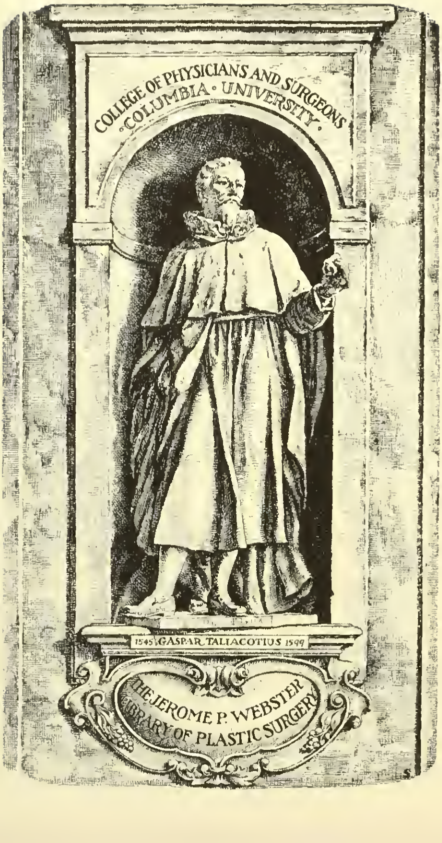
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AMERICAN PRACTICE OF SURGERY

A COMPLETE SYSTEM OF THE SCIENCE AND ART OF SURGERY, BY REPRESENTATIVE SURGEONS OF THE UNITED STATES AND CANADA

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* The news of Dr. Peters' unexpected death reached us just as these pages were passing through the press.—*Editors.*

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POISONED WOUNDS, INCLUDING THE BITES AND STINGS OF ANIMALS AND INSECTS.

POISONED WOUNDS, INCLUDING THE BITES AND STINGS OF ANIMALS AND INSECTS.

By Major CHARLES FIELD MASON, Surgeon, United States Army, Washington, D. C.

Poisoned wounds are broadly divisible into two groups—those in which the poison is of a chemical nature, and those in which it is microbic or bacterial in character.

Poisoned wounds by the implements of warfare sometimes belong to one class, sometimes to the other; they are of such a special nature that they are considered in a separate section.

When the poison introduced is of a chemical character the effect produced is prompt and dependent primarily upon the quantity of the poison introduced and its virulence; when the poison is bacterial, a certain period of time is required for the production of the toxin or the reproduction of the bacteria, and the effect produced is an increasing one, dependent on the growth and multiplication of the microbes.

The effect will also depend upon other factors, such as the physical condition of the individual and his powers of resistance at the time.

Insect Bites and Stings.—In these lesions a chemical poison, always of an acid nature, is introduced through a minute lesion produced by the bite or sting; as a matter of fact, the bite is not truly a bite, but rather a puncture, while the sting is also a puncture made usually by a modified ovipositor. The poison is secreted by a special poison gland or a modified salivary gland. No account is taken here of the special disease germs introduced through the bites of insects or by their mere contact with an abraded surface—such as malaria and yellow fever, filariasis, trypanosomiasis, etc.

Insect bites are usually a matter more of annoyance than of a serious nature, but where a large number of bites are inflicted at the same time, especially if the individual's resisting powers are low, they are capable of causing serious illness and even death. Thus, incidents are related of persons being stung to death by a swarm of bees, the fatal effect being largely due to shock, the result of the great amount of poison suddenly introduced.

When the bite is in a loose tissue, like that of the eyelids or lips, extensive œdema and swelling may be produced, but this is usually transient and not very painful.

The bites of the smaller insects, such as fleas, bedbugs, ticks, etc., cause only a slight irritation; those of mosquitoes often cause well-marked wheals which may persist for some time.

Bees, wasps, hornets, and yellow jackets inflict a sting which is much more painful in character and often attended with considerable swelling; where the stings have been multiple, considerable shock and constitutional disturbance are likely to result.

The treatment of insect bites ordinarily consists merely in extraction of the sting, when one is left in the wound, and the application of alkaline solutions,

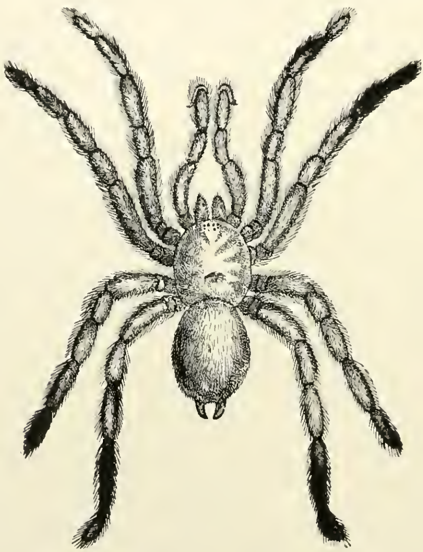

Fig. 1.—Bird Spider, or American Tarantula.

followed by antiseptic dressings if necessary. The alkalies found most useful are a dilute solution of ammonia or a saturated solution of soda. The application of moist earth or spider webs, so often recommended in such cases, is dangerous on account of the possibility of the introduction of tetanus spores.

The stings of tarantulas (Fig. 1), certain varieties of spiders, scorpions, and centipedes, are more severe and are stated to have even caused fatal results; such fatal results, however, are not well authenticated. Severe effects are sometimes produced: locally, inflammation and sloughing: and constitutionally, chills, fever, depression of the heart and respiration, headache, delirium and even convulsions. The larger the insect inflicting the bite, the more severe are the symptoms usually.

The tarantulas, scorpions, and centipedes are inhabitants of warm climates, the larger and more poisonous varieties being found in the tropics. All are nocturnal and predatory in their habits and furnished with poison glands. The *true tarantula* is found in Southern Italy and is a large, hairy spider with firm, hard mandibles adapted for piercing; through the hollow mandible the poison is injected. The large, *hairy spider* of the Southern and Southwestern States (Fig. 2) is also known as a tarantula and has the same arrangement of the biting parts.

Fig. 2.—Wasp Spider, a Large Formidable-Looking American Spider. Its bite is powerful, but does not produce serious results.

The large, tropical tarantulas are often brought to the Northern States on fruit-boats, in bunches of bananas or other tropical fruits.

The *scorpion* (Fig. 3), like the tarantula, hides away during the day in dark holes, under rocks, and sometimes in shoes or other articles of clothing, in closets, etc. It has a pair of mandibles by which it holds its prey, while the poison is injected through a sharp sting at the end of its tail. It is very rapid in its movements and runs about with its tail curved up over its back.

The *centipedes* (Fig. 4) resemble in their habits the tarantula and scorpion; the poison gland is in the head, and the poison is injected through a pair of modified legs.

Tarantula, scorpion, and centipede bites, when inflicted by large insects, and in children or debilitated subjects, may require treatment somewhat like that of snake-bite. If the case is seen at once, a ligature should first be applied around the extremity; then the wound should be incised and the poison sucked out; and, finally, a small quantity of a one-per-cent solution of potassium permanganate should be injected in the vicinity of the lesion. For the relief of constitutional symptoms morphine and stimulants may be necessary.

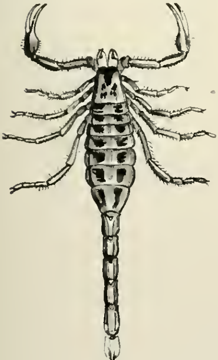

Fig. 3.—American Scorpion.

Bites of the Gila Monster.—Between the poisonous insects and the snakes may be considered the Gila monster (*Heloderma suspectum*) (Fig. 5), which has long been believed poisonous by some authorities, while others consider it harmless. It has even been stated that its breath is poisonous to small animals—sufficiently so at times to produce fatal results. It has no fangs or special poison gland, but it has grooved teeth connected with large salivary glands, and it saliva, as shown by Mitchell's experiments, is very deadly

when injected into pigeons. With regard to man there are many well-authenticated cases where its bite was harmless, while there are others in which it is stated to have produced fatal results. It is one of the largest known lizards, is marked with black and orange spots, and is found in Arizona, New Mexico, and Texas.

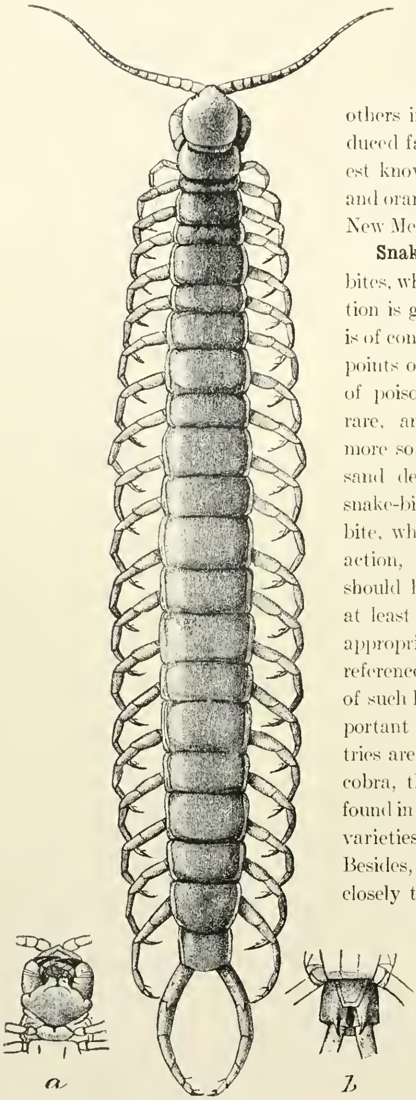

FIG. 4.—Centipede. *a*, Under side of head, showing fangs; *b*, under side of last segment.

Snake-Bites.—The subject of snake-bites, while one to which very little attention is given by the average practitioner, is of considerable importance from several points of view. In this country the bites of poisonous snakes are comparatively rare, and deaths from this cause still more so, but in India over twenty thousand deaths a year are reported from snake-bites alone. But a poisonous snake-bite, when it does occur, requires prompt action, and therefore every physician should have a knowledge of the subject at least sufficient to enable him to apply appropriate treatment at once without reference to the books. A wide diffusion of such knowledge becomes still more important now that so many tropical countries are coming under our control. The cobra, the most deadly of all snakes, is found in the Philippines, while other deadly varieties occur on the Isthmus of Panama. Besides, snake venoms have been found closely to resemble the products of bacterial growth, and their study has had much to do with the development of our knowledge of toxins, antitoxins, and immunity, subjects a thorough knowledge of which is essential to all physicians.

Snakes have no eyelids, and it is the absence of lids

which gives them the peculiar fixed gaze; they also have no external ear. They crawl by means of their movable ribs. All are carnivorous, swallowing their prey whole, the jaws being so arranged as to allow of lateral as well as vertical expansion. Some snakes are oviparous, while others, such as the vipers, are viviparous.

The great order of *Ophidia*, or snakes, is divisible into the suborders *Colubrines*, of which the greater part are harmless, and the *Viperines*, usually poisonous. The poisonous snakes are grouped together as *Thanatophidia*, or death snakes.

All snakes have sharply recurved teeth, the poisonous varieties being distinguished by the presence in the upper jaw of a set of one or more tubular or grooved fangs replacing the maxillary teeth, which are rudimentary or absent.

The shape of the maxilla and the arrangement of the teeth, being the most important means of distinguishing the poisonous from the non-poisonous snakes

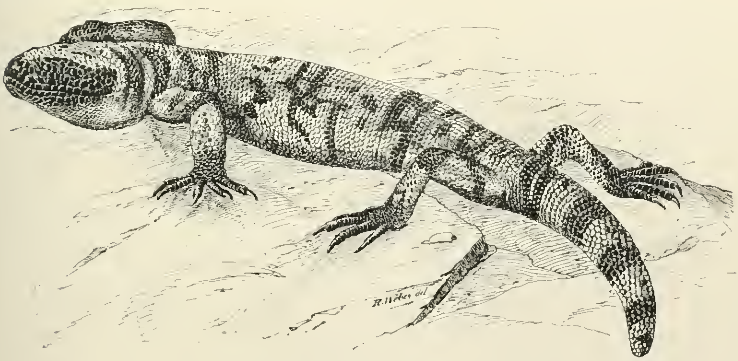

Fig. 5.—Gila Monster (*Heloderma suspectum*).

and the *Viperines* from the *Colubrines*, should be fully understood. Non-poisonous snakes have two complete rows of upper teeth and no fangs; this is a rule to which there are few exceptions. Poisonous snakes, on the other hand, have the palatine row complete, but the maxillary row is replaced by one or two fangs on each side (Fig. 6).

At the base of the hollow fang is the opening of the duct of the poison gland, which is situated behind the eye and is compressed by the same muscular action which closes the jaws, the action of injecting the venom being closely like that of a hypodermic syringe (Fig. 7).

Poisonous snakes are also distinguished by having on the under side, from the vent backward, one row of scales extending entirely across the abdomen, while the harmless varieties have two rows separated by a median line.

Another point worth remembering is that all salt-water snakes (Fig. 8) are poisonous, while all fresh-water snakes are harmless.

The Viperines are distinguished from the Colubrines by never having more than one fang (*f*) on each side, this fang being tubular and erectile, while in the Colubrines there is often a second set of fangs. The fangs are only about half the size of those of the Viperines, permanently erect and grooved. The Viperines have only from eight to ten palatine teeth (*p*, *pt*) on each side while the Colubrines have about twenty-five, and harmless snakes from thirty-five to forty. In Viperines the maxilla is very short, in poisonous Colubrines longer, and in the harmless varieties still longer.

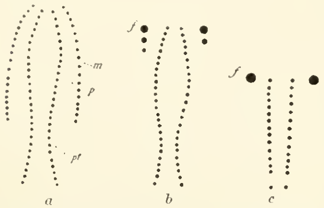

Fig. 6.—Tooth-Marks of: *a*, Non-poisonous snake; *b*, cobra; *c*, viper. The dotted lines are intended to show, not the actual number of teeth, but merely their relative arrangement.

The dentition of the *Hydrophidæ*, or water snakes, is similar to that of the non-poisonous land snakes, but this is the only exception to the general rule laid down.

The poisonous *Colubrines* are divided into two families: *Elapidæ* and *Hydrophidæ*. The *Elapidæ* have a cylindrical body, short tail, and not well marked neck, while the *Hydrophidæ* have a small head, long neck, and a body thicker toward the tail, which is compressed vertically to aid in swimming.

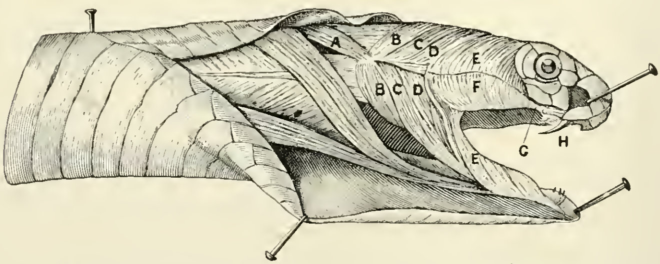

Fig. 7.—Muscular Apparatus and Poison Gland of the Cobra. *F*, Poison gland covered by the masseter muscle; *G*, duct of poison gland; *H*, fang connected with duct of poison gland. (Sir Joseph Fayrer.)

The Indian sub-families of Elapidæ are the *Najidæ* (hooded), including *Naja* and *Ophiophagus*, and *Elapidæ* (not hooded), including *Bungarus* (*Krait*) and others.

The American venomous *Elapidæ* (not hooded) include only the *Harlequin* and *Coral snakes*.

The Viperines have a broad, triangular, scaly head with distinct neck, short robust body, and sharp tail. They include: The *Viperidæ*, or true vipers, repre-

sented in India by the *Daboia russellii* and having no representative in North America; and the *Crotalidæ*, or *pit vipers*, distinguished from the true vipers by the deep pit between the eye and nostril. This family contains nearly all the poisonous snakes of North America, including the most deadly, the rattlesnake, and is comparatively unimportant in India. A few of the poisonous North American snakes are Colubrines, such as the coral snake and the harlequin snake. These latter, though smaller than rattlesnakes, are more deadly in proportion to their size; in structure they correspond more closely to the Cobra than any other American snake. The *Crotalidæ*, or *pit vipers*, include the rattlesnakes, copperheads, and moccasins.

FIG. 8.—Hydrophis Cyanocinta. A poisonous salt-water snake, found in the China Sea, near the Philippine Islands. Note the small head, pyramidal body, and flattened tail.

Rattlesnakes, of which there are a great many varieties in North America, are perhaps the best known of our poisonous snakes. The Northern species, the banded rattlesnake, *Crotalus horridus*, is from three to four feet long, while the diamond rattler, *Crotalus adamanteus* (Fig. 9), is a native of Florida and the Gulf States, where it attains a much greater size. The essential distinctive mark of Crotalus is the rattle, with which it makes the peculiar noise always heard when this snake is aroused. The number of rattles is not, as commonly supposed, exactly indicative of the age of the snake in years; in some years no rattle is produced, while in others several are produced.

The *Copperhead* (Fig. 10) and other species of moccasins are in some respects more dangerous than the rattlesnake, as they give no warning before striking, but fortunately their venomous properties are not so great in proportion to their size.

In India the most numerous and deadly snakes are Colubrines, such as the Cobra (Fig. 11) and Krait, though Viperines, such as Daboia or chain viper, are scarcely less important. In the Philippines also the cobra is found, though not nearly so commonly as in India.

Snake venom is a clear, limpid or viscid, yellowish fluid, acid in reaction, usually tasteless, drying without losing its poisonous qualities, and in this state, or dissolved in glycerin or alcohol, capable of indefinite preservation. The amount obtainable from a single large snake is from two to three cubic centi-

metres, but this will depend upon the size and activity of the snake and upon whether it has recently bitten. Chemically, snake venom contains several bodies, the most important being a globulin and a peptone. The proportion of these two principles varies in the different varieties of snakes, the globulin constituting about twenty-five per cent of the venom of the *Crotalidæ*, while it is present in less than two per cent in the *Najidæ*.

The globulins have a more decided effect upon the blood-vessels, destroying the coagulability of the blood, causing the corpuscles to become spherical and to stick together, and producing molecular changes in the capillary walls; this

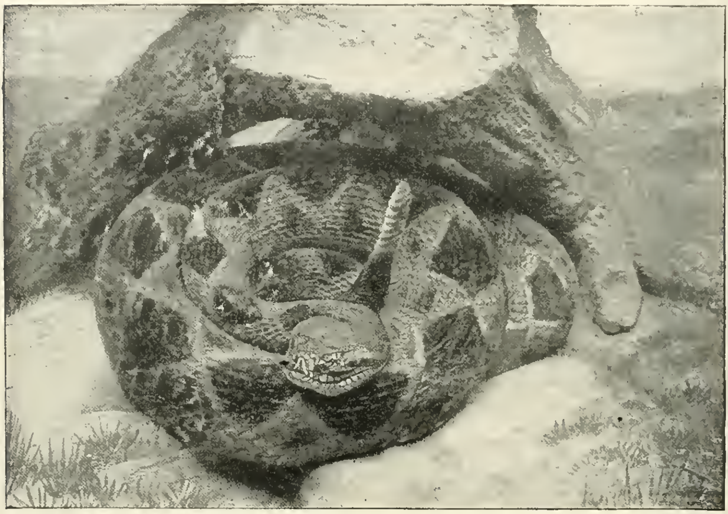

FIG. 9.—The Diamond Rattlesnake (*Crotalus adamanteus*).

latter change, together with the fluid condition of the blood, is the cause of the local and general extravasation, ecchymosis, and hemorrhage. The globulins accelerate the action of the heart, reduce the blood pressure, and act more promptly on the respiratory centre to paralyze respiration.

The local effect of the peptone is to produce rapid œdema, putrefaction, and sloughing without extravasation; constitutionally, it increases blood pressure, accelerates the respiration, and often causes convulsions.

The effect produced also depends on other circumstances. Thus, for example, if the poison is introduced directly into a vein, its action may be immediately fatal; the effects are more severe in hot weather and when the snake is well fed, and they are also more severe in the breeding season; if the supply of venom

has been recently exhausted by biting, the effect produced is of course much less; the size of the snake is also very important.

Cold has no effect upon snake venom, while heat impairs its toxicity; any of the chemical agencies which coagulate proteids will have the same effect upon venom. Potassium permanganate, tincture of the chloride of iron, and solutions of the hypochlorite of calcium are effective in this respect, though the permanganate is so rapidly destroyed by contact with the body tissues as to have less effect than when *in vitro*.

When taken into the empty stomach, venom, particularly the venom of the cobra, may produce poisonous effects, but it is rapidly destroyed when the stomach is full and its contents pass into the duodenum and come under the action

Fig. 10.—The Copperhead (*Ancistrodon contortrix*)

of the pancreatic juice. It is capable of some degree of absorption from the conjunctiva.

Elimination takes place by the various excretory organs and to some extent by the mucous lining of the stomach.

Symptoms.—The symptoms of snake-poisoning depend upon several factors already described; notably upon the species of snake, its size, condition as to fasting, the method of introduction of the poison, whether into a vein or subcutaneously, the condition of the person bitten, etc.

The Crotalidæ (**Rattlesnakes, etc.**).—In those who are bitten by this species of snake, the mortality varies from twelve to twenty-five per cent. The local symptoms are most marked—viz., pain, œdema, and extravasation of blood, followed by sloughing, gangrene, and suppuration. The constitutional symptoms are great prostration, dilated pupil, headache, dizziness, rapid and feeble

pulse, dyspnœa and shallow respiration, hemorrhages from the stomach and kidneys, nausea, vomiting, unconsciousness, convulsions, and death from paralysis of respiration. Not all of these symptoms, however, occur in any one case.

Death, when it occurs, is usually much more delayed than in cobra-poisoning, where it may occur in a few minutes, and, in the great majority of cases, actually does occur within twenty-four hours. The delayed deaths from rattlesnake-poisoning are really secondary, due to septic infection, the result of the action

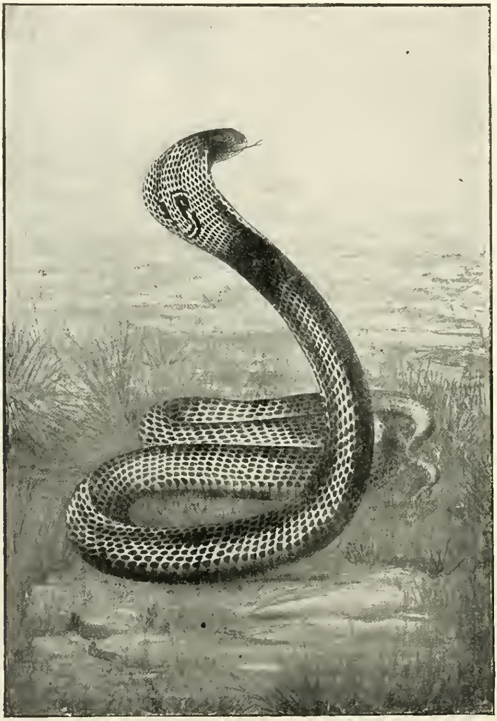

FIG. 11.—The Cobra (*Naja tripudians*).

of the poison in destroying the bactericidal power of the blood. It may also result from nephritis or other secondary effects upon the viscera. The action of the rattlesnake poison has been compared to that of the yellow-fever toxin, which it closely resembles, as will be seen from the preceding description of the symptoms produced by it. Recovery, when it ensues, is often quite sudden

and rapid, thus accounting no doubt for many of the vaunted cures by various specifics.

The bite of the moccasin or copperhead is seldom directly fatal, but may result in the loss of a limb or in a subsequent septicæmia.

To make the *diagnosis*, the bite should be examined. If the snake is harmless, two uniform rows of tooth-marks will be found; if there are two or more distinct fang-marks, with or without tooth-marks, the snake is poisonous (see Fig. 6). If the snake has been killed, the presence of the pit, in this country, will determine its venomous character; it must be remembered, however, that the very poisonous Coral and Harlequin snakes have no pit.

The *prognosis* will depend upon the many factors the bearing of which upon the issue have already been discussed. Fayrer believes that in India, when a vigorous cobra, krait, or daboia has bitten a human being fairly, with full penetration of the fangs, the result is uniformly fatal. Certainly such is not necessarily the case with the rattlesnake, the most venomous snake of this country, especially where treatment is promptly applied, as is usually the case.

Treatment.—After the poison has once entered the system it cannot be destroyed by any known chemical agent, because it is so like the other body proteids that a chemical substance which would destroy the venom would be likely to destroy vital proteids also. The most important point is to act promptly and intelligently, so that valuable time may not be lost in trying useless experiments; a delay of a few minutes makes all the difference between success and failure, life and death.

The first indication in treatment is to prevent absorption. This is done, if the bite is in an extremity, by immediately sucking the wound and tying a ligature tightly about the base of the part. This ligature should be applied a short distance above the bite and made as tight as possible so as completely to arrest the circulation, making the limb livid; it is well to apply one or more additional ligatures a short distance apart and higher up. If the extremity is small and unimportant, like a finger or toe, it may be better, after ligaturing, to amputate it at once. If the bite is upon the trunk, excision may sometimes be useful. After the application of the ligatures the extremity should be firmly bandaged from each end toward the wound to force out as much of the poison as possible, the wound itself freely incised, and the poison sucked out by the lips or by a cupping glass. If there is any abrasion on the lip, the mouth of course should not be used. If the case is not seen until some time after the bite, a half-hour or more, these measures are useless, as all of the poison will probably have been already absorbed. After the sucking, any poison remaining in the wound should be destroyed as far as possible by oxidizing or precipitating agents. The best of these are: one-per-cent solutions of hypochlorite of calcium, chromic acid, or potassium permanganate; tincture of iodine, bromine, the chloride of iron, bichloride of mercury, ammonia, etc., are also useful. If these chemicals

are not at hand the actual cautery should be applied in the shape of a hot coal, by burning gunpowder, or by other means. In order to prevent injury to the part from the arrest of the circulation by the ligatures, these should be cautiously loosened from time to time so as to allow restoration of the circulation, but they should be tightened up immediately upon the occurrence of any symptom indicative of renewed absorption.

The principle of the local treatment, then, is prompt action to prevent absorption, to get out of the wounds as much of the poison as possible, and to destroy what is left. As in very many cases the patients are not seen early enough to make the local treatment of value, the general treatment becomes of great importance, and the most effective measure of general treatment is the use of Calmette's antivenene in doses of from 10 to 20 c.c. of the stronger serum, to be administered hypodermically, as soon as possible after the bite. The serum has both curative and immunizing powers. In hermetically sealed vessels it keeps indefinitely, even in the hottest climates, though according to most authorities it loses somewhat in power under such circumstances. It is prepared on the same principle as is the antitoxin of diphtheria. The venom of several varieties of snakes—rattlesnake, cobra, and fer-de-lance—is dried and dissolved in water, 1 mgm. to the cubic centimetre; of this solution ½ mgm., representing half the lethal dose for a horse, is injected into that animal subcutaneously, and thereafter a gradually increasing dose is given every two or three weeks; after about a year the horse becomes so immune that it can withstand a dose of venom which would kill twenty-five non-immune horses, and after about a year and a half the serum is sufficiently strong in antitoxin to be of practical value, and is then ready for use after sterilization by heat.

Some authorities believe that antivenene is only effective against the bites of snakes of the same character as those from whose venom the antitoxin was prepared. Calmette, however, who holds that the essential death-producing principle of all snake poisons is the same, contends that his antivenene is effective against all sorts of snake-bites. Experience has demonstrated the essential correctness of Calmette's views.

After we have administered the antivenene, our efforts should next be directed to secure the elimination of the absorbed poison as rapidly as possible, and to combat its paralyzing effects upon the respiration and circulation. To effect the first object the stomach should be washed out, and cathartics given to remove the poison eliminated by the gastro-intestinal tract; water should be drunk freely and diaphoretics and diuretics administered. To secure the second end the measures which have been most highly commended are alcohol by the stomach, ammonia by the veins, and strychnine hypodermically—all powerful stimulants.

Perhaps the one remedy the laity thinks of in snake-bite is alcohol in the form of whiskey or brandy and in very large quantities—to the point of complete

intoxication; probably as many people have been killed by this treatment as have been saved by it. It is well established that men already "dead-drunk" have been bitten by snakes with fatal result.

The stimulating effects of alcohol are very desirable, and very large quantities may be taken in snake-bite without producing other than stimulating effects; but in complete intoxication the effect of alcohol is depressing and adds to the gravity of the situation. No fixed dose can be prescribed, but the alcohol should be given frequently and the effect watched, care being taken to stop short of intoxication.

Ammonia, administered by intravenous injection, was thought for a time to be a very valuable remedy, but experience is against its use in that way; it has value of course as a stimulant.

Strychnine, given hypodermically, appears to be a physiological antidote to some of the effects of venom; it must be administered in large doses to the point of manifesting its characteristic effects; as much as a grain or more has been given in twenty-four hours, but in broken doses.

Artificial respiration kept up for hours has proved useful where the breathing fails; and, in general, other unfavorable symptoms should be combated by appropriate measures.

When the venom has been injected upon the conjunctiva from a distance, as happens sometimes with the African cobra, violent inflammation follows and even symptoms of constitutional poisoning. In such cases the conjunctival sac should be immediately washed out by syringing with a solution of soda or by opening the eyes under water in such a solution. After the poison is thoroughly washed out, cold applications should be made and constitutional treatment employed if necessary.

Wounds in Which the Poison is Bacterial.—The ordinary septic infection of wounds by the cocci of suppuration comes under this heading, but wounds of that character are dealt with elsewhere.

Bites of man and other animals not rabid nor possessed of poison glands are of this nature also. Such bites, as is well known, often give rise to the severest form of septic infection and are sometimes followed by gangrene, pyæmia, and death. The infection in these cases is usually of a mixed character, streptococci and staphylococci both being found. Such wounds should always be thoroughly disinfected, free incisions should be made if necessary, and the exposed tissues should be washed with hydrogen dioxide; after which strong antiseptic solutions should be applied and moist antiseptic dressings laid over the parts. If the injury is seen late, after constitutional symptoms have supervened, the treatment must be conducted on the same general principles as those which govern the treatment of other cases of septicæmia and pyæmia.

Erysipelas.—Erysipelas is an acute infectious, febrile disease, characterized by inflammation of the skin or the mucous membrane adjacent thereto, and due

to the *Streptococcus erysipelatis* or *Streptococcus pyogenes*. This coccus is larger than the staphylococcus, aërobic, non-motile, non-sporogenous, non-liquefying, and stains with the usual reagents and by Gram's method.* It ordinarily forms chains, but may occur in pairs as diplococci. It is isolated by plating or by inoculation into mice.

The causal relationship of this coccus to erysipelas has been established by its fulfilling the requirements of Koch's tests, inoculation of pure cultures in man having frequently produced erysipelas.

Its identity with the ordinary streptococcus pyogenes has also been established, though for a long time it was believed by many that the streptococci causing suppuration, septicæmia, etc., were specifically different from the streptococcus of erysipelas. Experiment and further experience have shown that the streptococci from erysipelas can produce septicæmia, and that those from septicæmia can cause suppuration, and *vice versa*. As to which of these diseases will, in any given case, be produced by streptococcus infection we can only say that it will depend largely upon accidental circumstances, the part attacked, the virulence of the organism, and the resistance of the individual.

This streptococcus also causes acute ulcerative endocarditis, otitis media, meningitis, pneumonia, and pseudo-diphtheria, and it is the usual cause of the so-called terminal infections, which often contribute to the fatal ending in many acute and chronic diseases.

The cocci are found in the lymphatic capillaries of the inflamed part, but are not ordinarily found in the blood capillaries, except when there is some complication like septicæmia or suppuration. They are quite resistant to drying and the action of disinfectants; occasionally they may be identified in smear preparations, but, ordinarily, especially when they are sought for in the blood, cultures are necessary, often a large quantity of blood being used for the purpose. The vesicles which occur on the skin in erysipelas seldom contain the specific cocci, but they may be obtained in almost pure cultures from the serum escaping from small punctures made in the raised border at the edge of the erysipelatous patch. The toxins formed by the streptococcus are not well known.

In former days erysipelas occurred in epidemics, local as in hospitals, or widespread and fatal like that which from 1841 to 1849 spread over this country and Canada causing a high mortality. With the recognition of the nature of erysipelas and the consequent adoption of antiseptic measures of prevention, epidemics have about ceased.

Climate, season, and weather have been supposed to have considerable influence. The disease was believed to be rare in the tropics, but this is not borne out by American experience in the Philippines, where the disease occurs among American soldiers with about the same infrequency as in the

* "Textbook of the Pathogenic Bacteria." (McFarland.)

United States. It is also supposed to be more common in the spring of the year in cold, damp weather.

Infection commonly occurs through some small lesion of the skin or mucous membrane, though this lesion may be so minute as to be undiscoverable, or it may have healed, or finally it may be at some distance from the seat of the erysipelas. That the infection may, however, occur through some of the natural openings in the skin such as the ducts of the sweat glands, or through the hair follicles, seems probable from analogy, such inoculation having been effected with the staphylococcus.

In the vast majority of cases the disease first appears on the head or face, and, when one considers how very frequently small lesions of the face occur, this does not appear strange; it may, however, appear on the face secondarily, starting from a lesion in the nose and thence extending to the face.

The association of erysipelas with other diseases, acute and chronic, is usually of special interest etiologically; it will always be found that it is, like other cases of uncomplicated erysipelas, merely the result of the inoculation of some lesion such as a bed-sore in typhoid fever, or any of the solutions of continuity found in chronic skin diseases.

The association of erysipelas with puerperal fever and with scarlatina is, however, of so much importance as to require separate consideration.

That there was a close connection between puerperal fever and erysipelas was known for a long time before the discovery of the identity of the specific etiological factors in the two diseases. Physicians and nurses who were attending cases of erysipelas were observed to have many cases of puerperal fever among their obstetric patients, and this is not to be wondered at when we consider how numerous are the wounds of the puerpera about the vulva, vagina, and uterus, and the fact that erysipelas is an exceedingly contagious disease, that may be carried by hands, instruments, and dressings.

The relationship of scarlatina to erysipelas is probably not one of identity, though there are some who believe that scarlatina is a form of streptococcus infection. The fact that an attack of scarlatina affords marked immunity, while nothing of the sort occurs in erysipelas or any streptococcus infection, is against anything more than an accidental relationship of the two diseases, streptococci being frequently found in the inflamed throats and suppurative lesions of scarlatina patients and less commonly in the blood.

Relapses are of frequent occurrence in erysipelas, and recurrences after long intervals are sometimes so frequent as to justify the use of the term *habitual erysipelas*.

The relapses are probably due to the continued existence of foci of streptococcus infection, the activity of the organisms being lighted up by some accidental circumstance, such as exposure to cold or other depressing influence.

The cases of *habitual erysipelas* usually occur in individuals who have some

permanent lesion such as chronic skin disease, or abrasions in the genital tract; the frequent attacks being probably fresh infections through these lesions. In these cases there is also doubtless a special susceptibility, the result of enfeebled health.

An interesting phase of erysipelas is the curative influence which it sometimes exerts upon other diseases coexistent with it. This is seen not only in the more rapid healing of the wound through which the infection occurred, but in the cicatrization of chronic ulcers, the ulcers of lupus and epithelioma, and even in the absorption and disappearance of malignant growths. Fehleisen took advantage of his knowledge of this fact to demonstrate the cause of erysipelas by inoculating old ulcers with the streptococcus pyogenes, thereby inducing typical erysipelas. These observations have resulted in frequent attempts to cure such diseases by inoculation with the streptococcus, and there have been a number of successful results. But, as failures are also frequent, and as deaths have occurred from the resulting erysipelas, the treatment is only to be undertaken with caution and not as a routine measure.

The *pathological changes* found in erysipelas are flabby enlargement of the spleen and parenchymatous degeneration of the liver, kidneys, and heart, such as are common to other acute febrile diseases. Locally, in the inflamed area there are congestion of the capillaries, œdematous swelling of the skin and subcutaneous tissue, layers of leucocytes in the perivascular spaces, and a dense round-cell infiltration of the cutis and subcutis. At the margin of the inflamed area there are three zones: The outer, extending well beyond the area of visible changes in the surface of the skin, shows numerous streptococci in the lymph spaces; the next shows dense, round-cell infiltration with also numerous streptococci; while in the innermost zone the round cells only are found. When retrogression sets in, the round cells undergo degeneration and are absorbed, and the skin rapidly returns to a normal condition, no permanent change being left behind.

When complications such as gangrene, suppuration, and septicæmia occur, the characteristic tissue changes of those conditions are found.

The period of incubation of erysipelas is from eighteen to twenty-four hours. There are no prodromes. The disease usually begins with a chill, followed by high fever (102°–104° F.), severe headache, and more or less gastric disturbance. At the same time, about the wound, or, if there is none, on the skin, appears a flush attended with slight pain, feeling of tension, burning, and itching. Sometimes the local symptoms do not appear for twenty-four hours after the constitutional reaction, but usually the two are coincident. The red patch has a raised, sharply defined margin which is very irregular, extending out in tongues into the non-inflamed skin; the inflamed skin is tense and shining, doughy to the touch, and on its surface small vesicles develop which gradually become larger. The fluid in the vesicles is a yellow serum which becomes more

or less turbid and gradually dries up. The picture presented depends largely upon the location of the disease; in parts with a loose connective tissue such as the eyelids and scrotum there are great œdema and swelling. In such localities and over superficial bones like the olecranon, necrosis and sloughing are apt to occur.

The inflamed patches extend at their edges, the rapidity of spread being very variable—from one-half inch to eight or ten inches in the twenty-four hours; and they may involve large areas or the entire body. As the disease extends at the edges it clears up at the starting point, the same area of skin being usually not involved more than four of five days at a time. With the subsidence of the inflammation well-marked desquamation occurs.

The neighboring lymph nodes are early and constantly involved, becoming swollen and tender. Pain in the part is not very severe, but is increased by pressure.

Fever is constant and the course is very irregular, being marked by decided remissions with sudden rises on the involvement of new areas, and a tendency to become subnormal when the inflammation ceases. The pulse is increased in frequency and rapidly becomes weaker with the advance of the disease.

The tongue is heavily coated and the urine is loaded with urates and frequently contains albumin. There are marked headache and great restlessness, sometimes followed by lethargy.

Delirium frequently occurs and is usually transitory; it may, however, be due to meningitis. The changes in the blood, while of considerable interest, are not of much diagnostic value, as they occur only in the severe cases, in which the diagnosis is easy. These changes are: Increase in the fibrin and blood plates, reduction of the hæmoglobin and erythrocytes, and a polynuclear leucocytosis with diminution of the eosinophiles.

Phlegmonous Erysipelas.—This form of the disease is distinguished from the ordinary type by the fact that the cellular tissue is the principal seat of the inflammation. The swelling is greater and more boggy to the touch, and all the constitutional symptoms are more aggravated. Pus soon forms beneath the skin, and there are often extensive sloughs of the cellular tissue; indeed, in some cases the disease may involve the muscles and periosteum and lead to necrosis of bone or skin.

Facial Erysipelas.—Facial erysipelas is the same as erysipelas elsewhere, and is by far the most frequent form. It usually starts at the inner canthus of the eye or about the nose, and frequently extends to the scalp, neck, and chest, seldom however, involving the chin. There are usually conjunctivitis and œdema of the lids; occasionally the cellular tissue of the orbit is involved and there may be extensive suppuration, resulting in panophthalmitis and blindness; or the inflammation may extend to the brain membranes, causing meningitis and death.

Delirium is a more frequent accompaniment of facial erysipelas than of erysipelas elsewhere; occasionally it is due to meningitis, but more usually it is of a transitory nature, its exact cause in such cases not being fully understood.

Erysipelas neonatorum is a very grave form of the disease in infants, starting from the neighborhood of the umbilicus and extending to the abdomen and thighs. It occurs epidemically at times, and in infants under one month of age is practically always fatal. The infection may be from a mother suffering from puerperal fever.

Erysipelas may affect the mucous membranes primarily, especially the throat and nose, and the puerperal tract. Its course is much the same as that of a skin erysipelas, but there are no characteristic marks of an erysipelatous inflammation of these parts and it is not usually recognized until it has appeared upon the adjacent skin; the redness and swelling, however, often have a very well-defined margin and pain is usually severe; the enlargement of neighboring lymph nodes is generally marked. Erysipelas of the pharynx has occurred epidemically in a very severe form and probably has often been confounded with a diphtheritic inflammation of the part. The great danger here is that the inflammation may extend to the larynx and cause œdema of the glottis, a complication which is usually fatal.

Erysipelas may also extend to the lungs, causing bronchitis and a streptococcus pneumonia.

The *diagnosis* in skin erysipelas is usually easy; the shiny, red, swollen surface, with vesicles, and the irregular but sharply defined margin in a typical case, are lesions so marked that they can scarcely be confounded with those of any other disease. In less typical forms it must be differentiated from erythemata, phlegmon, lymphangitis, malignant pustule, and erysipeloid.

Erythemata are transient, usually afebrile, and have not the characteristic margin of erysipelas. In phlegmon the swelling is much harder; in lymphangitis the inflamed vessels can be felt as hard cords; in malignant pustule there is the depressed eschar in the centre, while microscopic examination and culture tests will reveal the presence of the Bacillus anthracis. Erysipeloid, while strongly resembling erysipelas, is an afebrile disease.

Complications.—A great majority of the complications of erysipelas are the result of the extension of the action of the specific streptococcus, and not the result of the invasion of other organisms. In the suppuration processes, however, the infection is sometimes a mixed one, staphylococci being also present.

In the skin occasionally abscesses develop or even gangrene; abscesses occur when the streptococcus invades the blood-vessels, while gangrene is specially liable to result where the skin is stretched over superficial bones like the elbow, or where the tissues are loose, as in the scrotum.

Other complications are: Cellulitis, which, when it affects the orbit, often causes blindness; suppurating bubo; meningitis; lobar and broncho-pneumonia;

endocarditis; nephritis; otitis media; suppuration in the frontal and maxillary sinuses, and general sepsis.

Prophylaxis.—This is not difficult when it is remembered that the infection is readily carried on the hands, clothing, instruments, and dressings, and that the streptococci are found in the air around erysipelas cases. It must also be borne in mind that any one of the streptococcus infections may reproduce any other, that hands infected by a patient with septicæmia may carry erysipelas to another patient, and that infection from the latter may produce puerperal fever in a parturient woman.

Erysipelas has been brought into surgical wards by patients with sore throats, the nature of which was not suspected until the erysipelas made its appearance on the face.

The efficacy of, and at the same time the necessity for, prophylaxis are shown by the great reduction in the number of cases of hospital erysipelas since the introduction of antiseptic methods.

Treatment.—This may be considered under three headings—specific, general, and local.

By specific treatment is understood the use of antistreptococcus serum. This is prepared in very much the same manner as is diphtheria antitoxin, and is given in the same way in doses of 20 to 30 c.c., to be repeated if necessary. The original serum of Marmorek was prepared from the streptococci from one source, while some of the later sera are prepared from a mixture of streptococci from various streptococcus diseases. The reports as to the efficacy of the treatment are very conflicting, but the weight of the evidence is against its having any value, and it has produced very unpleasant and even serious symptoms.

The general treatment is largely symptomatic, though almost specific effects have been claimed for the tincture of the chloride of iron, given in doses of from twenty to thirty drops every two or three hours, for a period of several days. The bowels should be moved by laxatives, and nourishment must be given freely and in concentrated forms. If there are much headache and delirium the ice-cap may be applied and phenacetin given internally, or tepid baths may be used.

Locally, treatment has for its object to prevent the spread of the disease and to relieve the pain and burning by preventing the access of air to the part by means of ointments and antiseptic dressings.

To prevent the spread of the disease, both mechanical and chemical means have been employed. Kraske makes a series of incisions through the skin, crossing each other just beyond the raised border and so arranged as to include the entire inflamed area; an antiseptic solution is then rubbed into the incisions and a wet antiseptic dressing applied. Hunter makes injections of two-per-cent carbolic-acid solution into the margins of the patch, and Wölfler applies compression with adhesive-plaster strips. All of these methods are painful and none seems to offer any special advantage in results.

To relieve the pain and tension, ointments, powders, and lotions of various sorts are employed. These are generally of an antiseptic or emollient nature. Very good results are claimed for an ointment of ichthyol twenty-five to fifty per cent, while other surgeons have been equally successful with wet applications of phenol one-fourth to one per cent, according to the extent of surface involved, or watery solutions of bichlorid of mercury 1 : 2,000. Of powders, one of the most useful is composed of salicylic acid 3 parts, talc 87 parts, and starch 10 parts. That one of these agents which is most comfortable to the patient is the best.

When there is a great deal of œdema, as about the eyelids or scrotum, acupuncture often gives considerable relief.

In the phlegmonous form of erysipelas free incisions must be made to evacuate pus and sloughs, the wounds thoroughly irrigated and drained, and the whole part covered with warm, wet antiseptic dressings, to be changed frequently; or, if practicable, the part may be immersed in an antiseptic bath.

Prognosis.—In primary skin erysipelas, without apparent lesion, the prognosis is very good, the mortality being from one to five per cent; where there is a wound present, the larger and more serious the wound the worse the prognosis. In erysipelas of the larynx the prognosis is bad; it is also bad when the disease affects the female genital tract, and very bad in case of general sepsis.

In chronic alcoholism, and when the erysipelas occurs as a secondary infection in chronic diseases, the outlook is very unfavorable.

Sequelæ.—Simple, uncomplicated erysipelas has no sequelæ. When there are frequently recurring attacks a thickened condition of the skin, approaching that of elephantiasis, may result.

In the phlegmonous form we may have extensive destruction of tissue, which leads to deformities and loss of function. Blindness, organic heart disease, nephritis, etc., may result, as already stated under complications.

Tetanus.—Tetanus is an infectious disease which nearly always develops as a sequence of a wound. It is usually sporadic, but at times prevails epidemically; it is characterized by trismus and general tonic convulsions, and is caused by a specific bacterium, the *Bacillus of Nicolaier*, the toxins of which when absorbed expend their force upon the central nervous system.

The bacillus of tetanus was discovered in 1885 by Nicolaier, from whom it derives its name, and was first isolated in pure cultures by Kitasato in 1889. It is a rod bacillus with a spore at one end, that gives it the shape of a club; it is motile, flagellated, anaërobic, and liquefying, and stains by Gram's method.* It is very widely diffused, being found in street dust and dirt, in garden soil, in stables, under the finger nails, and occasionally in the human intestinal tract. It also occurs in the intestines of herbivora who take it up with their food from the ground, upon cobwebs, etc., and only the fact that it is anaërobic and does

* "Textbook upon the Pathogenic Bacteria." (McFarland.)

not grow well upon surface wounds prevents the disease from being very much more common than it is.

In the body it is found only in the tissues of the wound, very rarely in the blood and internal organs. It produces a soluble toxin, tetanin or tetano-toxin, to which the symptoms are due.

Various products have been found in the tetanus toxin. Ehrlich isolated two bodies, one of which he called tetanospasmin and the other tetanolysin, the former being the principal cause of the spasms and the latter of the hæmolytic action of the toxin. This toxin is the most poisonous known substance, a fifth of a milligram being a fatal dose. Like snake poison it is comparatively harmless when taken by the mouth, unless there is some abraded point through which it can be absorbed.

The tetanus bacillus is exceedingly resistant, and a place once infected is apt to remain so for years.

The prevalence of the disease is influenced by weather, climate, and race; warm weather, hot climates, and the dark race all being favorable to the growth of the bacillus.

Tetanus is especially apt to follow gunshot wounds and particularly those inflicted by the toy pistols with blank cartridges. Tetanus after gunshot wounds was much more frequent in ancient times; during the Civil War it followed gunshot wounds about once in six hundred times, while in about fourteen hundred such wounds in the Santiago campaign there was no case of tetanus. This diminished frequency of the disease is due rather to the clean-cut character of the wound inflicted by the modern small-arm than to the general adoption of antiseptic methods. On the other hand, the alarming frequency of tetanus following blank-cartridge wounds, as evidenced by the fact that four hundred and fifteen cases of tetanus were reported as following Fourth-of-July accidents in 1903, is also due to the special characteristics of these short-range accidents. It was at first supposed that the cartridges were infected in these cases, but experiments have shown that this is not the case, but that the tetanus bacillus is probably on the soiled hands of the children among whom chiefly these wounds occur, and is carried into a wound specially suitable for its culture by reason of its lacerated character, of its tendency to retain foreign bodies, of some favoring influence exerted by the powder burn that always forms a part of these wounds, and of the presence of a hæmatoma.

The gross changes found after death from tetanus are not marked, hyperæmia of the vessels of the brain and spinal cord being about all that is seen. Microscopic examination of the sections of the central nervous system shows intense capillary congestion with exudation in the perivascular spaces and occasional small ecchymoses. An ascending neuritis has been described by some writers, while others have found evidences of softening in the gray matter of the anterior cornua.

Certain changes are usually found in the wound, which has an unhealthy appearance and often contains small collections of dirty pus.

The toxin, upon which the symptoms of the disease are dependent, is supposed by some to act directly upon the spinal cord, increasing its reflex excitability; by others it is believed that the tonic muscular contractions are the result of a direct action upon the motor centres of the brain.

When the toxin is injected into a muscle it has a direct local effect in causing spasm; hence the spasm is sometimes felt first in the neighborhood of the wound. Zupnik thinks there are two distinct actions of the toxin: a tetanus ascendens—the tonic spasm due to the local effect; and a tetanus descendens—the action upon the spinal cord that causes clonic convulsions, trismus, and opisthotonos. He believes that the trismus and opisthotonos are due to the insufficiently opposed action of particularly powerful groups of muscles.

The disease is a pure toxæmia, the bacillus itself never entering the blood. The wounds in which it occurs are wounds into which infected earth has been rubbed, and infected deep wounds.

The period of incubation of the disease is very variable—from a few days to several weeks, the average being about nine days.

Formerly, there were believed to be two essential varieties of tetanus—traumatic and idiopathic; we now believe that all cases are traumatic, though the trauma through which the bacillus enters may often be very small and impossible of detection.

Ordinary traumatic tetanus following a visible wound may be acute or chronic.

In the acute form the disease lasts a week or ten days, and it usually ends fatally; but sometimes it gradually assumes a chronic character and then offers some prospect of recovery.

The first symptom is generally trismus or lock-jaw, from which most prominent symptom the disease acquires its popular name. Often, however, the first symptom complained of is stiffness of the neck. The trismus is followed by spasm of the muscles of the neck and back causing opisthotonos and spasm of the abdominal muscles, which become hard and plaque-like; and afterward come inability voluntarily to evacuate the bowels or bladder, and spasm of the muscles of deglutition, causing difficult swallowing. After these, contraction of the muscles of the lower extremities may be observed, and, lastly, the upper extremities may become involved, though this is unusual. The spasm of the muscles of the face causes retraction of the lips and exposure of the teeth, together with lifting of the eyebrows—changes that produce a horrible smile, the *risus sardonicus*, which, however, is not always present.

The spasms, which cause great pain and exhaustion, are aggravated by the slightest noise or motion, and may be so severe as to cause rupture of the muscles or even fracture of the bones. Swallowing food is difficult, and sleep impossible,

and exhaustion supervenes with more or less rapidity according to the severity of the symptoms. The skin is bathed in perspiration and there is little or no elevation of temperature until perhaps toward the end. The mind remains clear until the last, and death usually occurs in one of the convulsions, from interference with respiration; or, if it occurs at a later period, it will be due to exhaustion or to sudden heart-failure. During sleep, artificially or naturally induced, the muscles relax.

To recognize the trismus, the most important symptom, we must exclude inflammatory conditions about the wisdom teeth and in or about the tonsils. If the fingers of the examiner are introduced between the cheek and the teeth, they will feel the firm edge of the contracted masseters, the same on both sides. An examination of the neck will reveal the fact that the chin cannot be approximated to the chest and that firm pressure on the neck causes no pain.

The contraction of the muscles of the neck and back, which gives rise to opisthotonos, may gradually increase until the occiput nearly or quite touches the back. Under these conditions the whole body forms an arch with the concavity backward, no part touching the bed except the occiput and heels upon which the body rests. These cases are usually fatal, though recovery may ensue even when the symptoms are so severe. When such a change for the better occurs it will be evidenced in the following manner: the jaw can be gradually opened more and more, the muscles of the neck and back slowly relax, and nourishment can be taken. On the other hand, a sudden relaxation of the masseter, the jaw dropping, is a symptom of bad omen; it is usually followed by a rise of temperature, with a rapid and thready pulse, and death quickly ensues.

Not always does the tetanus follow such a typical course; sometimes the acute case gradually assumes a chronic type, or acute symptoms may suddenly supervene upon a chronic and delayed case.

In *chronic tetanus* the symptoms come on later and are more gradually developed; between the spasms there are intervals in which the patient can get more or less rest and take nourishment; the later the appearance of the symptoms the less marked they are, as a rule. In some of the milder cases the patients are not even confined to their beds, going about as usual and complaining only of some stiffness of the neck and difficulty of swallowing. Such cases are, no doubt, often overlooked or mistaken for sore throat or some other milder affection; their importance lies in the fact that they may suddenly assume a severe and fatal form.

Tetanus neonatorum is a very fatal form of the disease. It occurs in infants and is due to infection of the umbilical cord, through the filthy customs of the class of people among whom it prevails. It occurs especially in the tropics, and at times epidemically; in certain regions, as in the Philippines, a large proportion of the deaths among native children during the first two weeks is due to this cause. The disease is often overlooked. The most prominent

symptom is trismus, which renders the child unable to nurse or cry; death usually occurs in forty-eight hours, from general convulsions or from exhaustion and inanition.

Facial tetanus is a variety of the disease following injury within the area of distribution of the facial nerve. It is the only form of tetanus associated with paralysis—in this case, of the facial nerve. It is characterized by the prominence of the symptoms of dysphagia, resembling rabies in this respect, and by the absence or greatly diminished intensity of spasm of the muscles of the trunk and lower extremities.

The paralysis of the facial is probably to be attributed to mechanical injury to that nerve, as the tetanus toxin appears to have no power to cause paralysis.

While the convulsions are less general and severe in this form, the attack is hardly less serious in its consequences, on account of the early occurrence of inanition, the result of difficulty in swallowing. It is a comparatively rare form, for tetanus of the face constitutes only about five per cent of the cases, about eighty per cent resulting from wounds of the extremities, and ten per cent from wounds of the trunk.

As *complications* of tetanus are occasionally found acute bronchitis and pharyngitis and lobar or lobular pneumonia.

The *sequelæ* are marked anæmia, swelling of the extremities, stiffness and soreness of the joints and muscles.

Diagnosis.—The diseases with which tetanus is liable to be confounded are tetany, strychnine poisoning, hysteria, rabies, cerebro-spinal meningitis, abscess of the cerebellum, myositis of the muscles of mastication, and inflammatory conditions about the teeth and tonsils.

In the first place, a careful examination should be made of the entire surface of the body, particularly the extremities, the genital organs, and the nose and throat, for any wound, or the presence of a splinter or foreign body, however small; inflammation about the wisdom teeth or the tonsils should also be sought for.

Then the presence of trismus, and its degree, should be ascertained by feeling for the firm border of the masseter between the teeth and cheek; in the healthy condition the masseter cannot be felt when the mouth is open; in tetanus it is firmly contracted on both sides. Opisthotonos is to be looked for by endeavoring to approximate the chin to the chest, and the muscles of the neck should be firmly compressed to ascertain the presence or absence of tenderness.

The history of the patient is of importance; our effort should be to ascertain whether he has been about stables or horses or has handled manure, dust, or earth, and also whether he has recently seen a case of tetanus in man or beast.

Tetany is a condition not due to infection with the bacillus of Nicolaier; it occurs chiefly in young females during pregnancy or lactation, after mental

shocks, in dilatation of the stomach, and after operations for goitre. It is characterized by recurring attacks of spasm, principally in the hands and upper extremities, though they may become general; there is, however, no trismus nor opisthotonos, and there are always distinct intermissions.

The distinctive features of strychnine poisoning are: the purely reflex nature of the spasms; the fact that they begin in the extremities, while tetanus begins usually with trismus; the distinct intermission; the rapid supervention of exhaustion and unconsciousness, and the speedy termination in death. Of course, the poison can readily be detected by chemical tests and there may be also the absence of any wound.

Hysteria at times simulates tetanus as it does almost all other diseases, but the resemblance is a superficial one and it is only necessary to bear it in mind to make the distinction.

Rabies and tetanus are sometimes confounded, though the differences are very clear. In rabies there is neither trismus nor opisthotonos, and the spasm of the muscles of deglutition, which sometimes occurs also in tetanus, is accompanied in rabies by early exhaustion with paresis or occasionally paralysis. After death, a subdural injection of an emulsion of the central nervous system of the cadaver will, in the case of rabies, reproduce that disease, while in the case of tetanus the central nervous system is incapable of producing any infection.

In cerebro-spinal meningitis there are stiffness and retraction of the neck, but the disease is distinguished from tetanus by the fever, slow pulse, headache, delirium, stupor, vomiting, hyperæsthesia, and the pain elicited by pressure on the neck, all of which usually occur in the former disease but not in the latter; a microscopical examination of the cerebro-spinal fluid withdrawn by aspiration will settle the diagnosis.

Abscess of the cerebellum is distinguished from tetanus by the presence of severe headache and the absence of trismus.

Inflammation of the muscles of mastication is distinguished by the tenderness and swelling involving the temporal muscle and by the absence of opisthotonos and general spasm.

The *prognosis* of tetanus is grave in all cases, depending on the variety of the disease, the length of the incubation period, the character of the wound, and the completeness of the trismus. In traumatic tetanus the mortality is about ninety per cent, being graver the more extensive the wound and the greater the tendency to gangrene; in facial tetanus the mortality is about seventy per cent; in tetanus neonatorum it is about the same. The shorter the incubation period and the more complete the trismus, the graver the prognosis; with an incubation period of less than ten days the mortality is about ninety-five per cent, while for periods greater than ten days the mortality is much less.

The prognosis is more favorable in those cases in which the antitoxin has been used, and the earlier it is used the better the prognosis.

Tetanus is very easy to prevent in some cases if suitable measures are adopted, immediately after the infliction of the wound, for the destruction of the infective agents, but it is very difficult to cure after it has become established. When the symptoms occur and the disease is recognized, toxæmia has already occurred and a certain amount of toxin has become fixed in the nerve cells.

Treatment.—The specific treatment—and at the same time the treatment which offers the best prospect of cure—is that by tetanus antitoxin, and yet the results of its use for curative purposes have been disappointing. The reason of this is to be found in the intensely poisonous nature of the toxin, its early fixation in the nerve cells, and the enormous increase in the amount of antitoxin required for each hour and day of delay in treatment. While the curative powers of the antitoxin are thus limited, its prophylactic powers are very great. Those who use it early in wounds of such a character as are likely to be followed by tetanus, have no cases of that disease to report; there is no doubt but that it should be used in this way in all suspicious wounds.

Wounds caused by blank cartridges and others of like suspicious character should be thoroughly opened up and disinfected under anæsthesia, if necessary. The part should be rendered bloodless, all the ramifications of the wound should be carefully sought out and freely opened, and foreign bodies of all sorts, including blood-clots and shreds of tissue, should be removed; after which the wound should be washed out first with antiseptics, and then with a normal salt solution, and loosely packed with iodoform gauze. An antiseptic dressing should be applied over the part.

As the next step in the treatment, an immunizing dose of antitoxin serum, ten to fifteen cubic centimetres, should be injected intraspinally, the same amount of cerebro-spinal fluid having been first allowed to escape. A fairly large-sized needle such as is ordinarily used in spinal anæsthesia is introduced between the third and fourth lumbar vertebræ and the injection slowly and carefully made. In addition, from ten to fifteen cubic centimetres should be injected directly about the wound, and ten cubic centimetres, or as much as practicable, into the sheaths of the principal motor nerves supplying the part. For the intraneural injections the nerve trunk should be exposed as high up in the limb as practicable, and a fine needle used. Trephining and intracerebral injections do not seem to give better results, and are attended with a certain amount of danger. If symptoms of tetanus have already developed, the treatment should be the same, and the injections may be repeated daily for two or three days. The patient must be put to bed in a darkened room and kept absolutely quiet. Nourishment should be given by the rectum if necessary, and with as little disturbance as possible. The urine must be drawn and the evacuations of the bowels looked after.

The medicines which have given the best results are opium, chloral, and chloroform; they must be used freely in such a manner as to secure decided effects. Chloral is often advantageously administered by the rectum. Chloroform is, of course, given by inhalation, and the patient may often be kept under its influence for hours, with the same happy results as in puerperal eclampsia. It must not be forgotten, however, that the commencement of its administration may excite a convulsive seizure, and that, when it is stopped and the effect passes off, there may occur a spasm of such increased severity as to terminate in death.

Malignant Œdema.—A diffuse, rapidly spreading, gangrenous inflammation which is due to infection with the *bacillus of malignant œdema*, and in which the tissues become distended with gas. The bacillus is a large rod resembling that of the anthrax bacillus; it is flagellated, motile, sporogenous, anaërobic, gas-producing, and liquefying, and does not stain by Gram's method.* It is found in garden soil, in dust, in waste-water from dwellings, and sometimes in the intestinal canals of animals. In infections of man it is usually found associated with the ordinary germs of putrefaction; in the soil it is found in association with the tetanus bacillus. Its inoculation upon the surface of open wounds does not result in infection on account of the free access of air; but when it is introduced deeply in the tissues infection follows. It is found in the living tissues, but not ordinarily in the blood until after death—this on account of the presence of loosely held oxygen in the circulating fluid.

Malignant œdema is a rare disease, much more so than gaseous œdema due to the *Bacillus aërogenes capsulatus*, a disease which may be mistaken for it. There are only five cases of true malignant œdema on record (Gould). It is a fact of interest in this connection that an examination of the recently prepared poisoned arrows used by the natives of the New Hebrides has shown the presence of the bacillus of malignant œdema, coincidently with that of tetanus. The arrow points are poisoned by dipping them into the mud of crab holes.

The local symptoms are those of a rapidly spreading gangrenous inflammation with emphysema of the tissues. The skin of the infected area is of a brownish or black color, crepitates freely under pressure of the fingers, and is covered with blebs containing a foul-smelling, sanguineous fluid. The wound is inflamed, gangrenous, and bathed in the same fetid, brown fluid containing gas bubbles. The general symptoms are: profound depression, rapid development of high fever, quick pulse, dry brown tongue, delirium or apathy, and great thirst, followed by death in from twenty-four to forty-eight hours. After death, putrefaction develops with remarkable rapidity, the body swelling to great size from gaseous distention of the tissues.

The *diagnosis* is readily made; the only infection with which this disease is

* "Textbook upon the Pathogenic Bacteria." (McFarland.)

liable to be confounded is that due to the *Bacillus aërogenes capsulatus*, from which disease it can be distinguished by microscopic examination of the tissue fluids for the specific bacilli.

The *prognosis* is bad, the infection nearly always proving fatal.

The *prophylaxis* is indicated by a knowledge of the ways in which infection occurs. Sometimes it follows serious injuries like compound fracture, in which dirt is ground into the wound, and sometimes it develops after the most trivial accidents, such as punctured wounds with garden tools, the use of the hypodermic needle, and even the bites of insects.

The *treatment* must be prompt and of the most radical nature. If the disease develops in an extremity amputation should be done at once, well above the œdematous area; if it develops in some other situation complete excision is the only resource. If these measures are not practicable free incisions must be made to relieve tension and give exit to the products of inflammation.

After this, the part should be immersed in a hot antiseptic solution or kept covered with wet antiseptic dressing which should be frequently changed.

Constitutional treatment must be of the most supporting kind—stimulants, tonics, and concentrated foods.

Gaseous Œdema.—A condition of widespread emphysematous cellulitis or gangrene developing usually a short time before death and due to infection of a wound with the *Bacillus aërogenes capsulatus* (Welch).

This bacillus is a large stout rod, anaërobic, sporogenous, non-motile, non-flagellated, gas-producing, and stains readily by Gram's method.* It was first isolated by Welch from the body of a man who died suddenly of aortic aneurism and whose connective tissues and blood-vessels were full of gas. Infections with this bacillus have since been reported from a number of sources—the gastro-intestinal and genito-urinary tracts, the lungs, etc. Pure cultures have been found in the peritoneal cavity, but the infection is usually a mixed one.

These organisms are widely distributed, having been found in the soil, in the intestinal tract of animals, and upon the skin. Infection is especially apt to follow wounds that are brought in contact with earth or with intestinal contents. It has followed compound fracture, ulcers of the stomach and intestine, abortion, and operations for strangulated hernia. After death the tissues and organs are found full of gas bubbles, the organs having a frothy appearance and feeling as if they were full of air. The bacilli in the organs are found in pure culture, while in the wound they are usually mixed with pus cocci. The muscles and other tissues show degenerative changes.

The local symptoms are redness and rapid emphysematous swelling of the wound, from which flows a brown, frothy discharge. The emphysema quickly

* "Textbook upon the Pathogenic Bacteria." (McFarland.) See also Fig. 131 on page 459 of volume II.

spreads and may cover the entire body. If there is no external wound the emphysema may be the first symptom to attract attention.

The constitutional symptoms are: Profound depression, rapid pulse and high temperature, usually quickly followed by death, though recovery has occurred.

The *diagnosis* is to be made from malignant œdema, which it closely resembles, and, as a rule, it is possible to differentiate the two diseases only by a comparison of their respective bacilli in the tissues.

The *prognosis* is very unfavorable, though recovery is possible when the wound is so situated that amputation can be performed early.

The *treatment* of gaseous œdema is practically the same as that for malignant œdema. Prompt amputation should usually be done if it is possible to get beyond the limits of the disease, though if the case is seen early it may be practicable in some cases to save the limb. If this is not possible, the best course is to make free incisions, to disinfect the parts thoroughly, and then to apply wet antiseptic dressings. The constitutional treatment should be of the most supporting kind—stimulants, tonics, and nutritious foods.

Anthrax.—An acute, infectious disease that is due to inoculation with the *Bacillus anthracis,* and that occurs in man occasionally, but with much greater frequency in sheep and cattle.

The *Bacillus anthracis* is one of the largest and is among the earliest and best known of the pathogenic germs. It is aërobic, sporogenous, liquefying, non-motile, non-flagellated, and stains with Gram's method.* It is particularly interesting as being one of the pathogenic bacteria which, so far as is known, produce no toxin, death being in part due to the obstruction of the blood-vessels by the swarms of bacilli and in part to their appropriation of the oxygen in the blood, leaving the tissues to be poisoned by the carbon dioxide.

The bacilli themselves are readily destroyed, but the spores are very resistant, and it is principally through them that the disease is spread. The bacilli are destroyed by the gastric juice, but the spores pass through the stomach unchanged and, finding suitable conditions in the intestine, rapidly proliferate there, make their way between the epithelia, and enter the lymphatics and blood-vessels.

In animals, infection occurs chiefly by inhalation or swallowing of the germs or their spores in feeding on infected areas; occasionally it may occur through the bites or stings of insects. In man the disease may also follow inhalation or ingestion of the bacilli or spores, but, more commonly, it results from direct inoculation.

The disease is specially apt to occur in those whose occupation involves the handling of the hides and hair of animals subject to anthrax. It occurs, therefore, chiefly among shepherds and stablemen, workers in wool and hair, and especially among tanners. It is comparatively rare in this country, but is quite common in Eastern Europe and in Asia.

* "Textbook upon the Pathogenic Bacteria." (McFarland.)

In man, anthrax occurs in two principal forms—internal anthrax and external anthrax. Internal anthrax is variously known as wool-sorters' disease, rag-pickers' disease, splenic fever, and mycosis intestinalis; and external anthrax is termed malignant pustule or charbon.

The internal forms, in which the infection occurs through the gastro-intestinal or the respiratory tract, present the symptoms of an intense septicæmia, and are not usually recognized unless there is some special reason which points to anthrax infection. It is not a surgical affection, though it is frequently associated with carbuncles or other lesions of the skin.

The external variety of anthrax occurs in two forms—the malignant pustule or charbon, and anthrax œdema; the two may be associated.

Malignant pustule usually occurs upon the hands, arms, or face; if it occurs upon the face the infection is generally carried there by the fingers. It may be conveyed by the bites of flies or other insects, or their mere contact with a wound or abrasion may be sufficient to effect inoculation if the insect is infected.

The first sign is an itching papule which rapidly becomes vesicular; the vesicle is filled with a sanguinolent fluid, and surrounded by an area of dense infiltration often with extensive œdema, especially in parts containing loose cellular tissue, like the eyelids and lips. The lymph channels and nodes are quickly involved and become swollen and tender; the vesicle breaks and is replaced by a dry, brown eschar or slough which is firmly adherent, tough and occasionally spreading. Surrounding the primary lesion may be other vesicles which in turn give place to sloughs.

There is a rapid rise of temperature and pulse; the temperature, however, does not stay up, but falls in a few days to or below normal. The mind is usually clear unless general infection occurs; when this happens, there may be severe chills, vomiting, and great depression, followed by delirium and stupor.

Anthrax œdema is distinguished by the absence of the papule or vesicle and the greater prominence of the œdema, which is often very extensive and may be followed by gangrene. Like charbon it also occurs especially about the face and is very fatal.

The diagnosis is to be made from the character of the lesion and the history of the case, especially with regard to occupation and possible exposure to infection, but above all by finding the specific bacillus in the lesions.

The relative absence of pain, tenderness, and pus, as compared with what is observed in the ordinary carbuncle, is a distinguishing feature, but the bacilli are usually found without trouble in the vesicle and identified by culture and inoculation, if necessary.

Anthrax œdema is liable to be mistaken for malignant œdema, from which it can usually be differentiated by an examination of the blood for the specific bacilli; sometimes these do not appear in great numbers in the blood until just before death, but they can readily be found in the tissues of the infected region.

The prophylaxis of anthrax, so far as concerns the control of the disease in animals, and the sanitary measures to be adopted in the trades which involve exposure to infection, are matters the consideration of which would carry us beyond the limits of this article.

The prophylaxis to be observed by those who have the care of anthrax patients involves the utmost care in the handling of the patient, his dressings, and the discharges; dressings and discharges should be at once disinfected or destroyed and the attendants should frequently disinfect their hands, mouths, and nostrils, and carefully avoid scratching any part of the person.

Until recently the treatment of malignant pustule has either been expectant —rest, soothing antiseptic ointments, and supporting diet, tonics and stimulants—or has been based upon active interference, such as free incision or excision, or the use of caustics, one or all.

As the fatal result in charbon is always due to general infection the treatment should be of such a nature as to prevent that infection as far as possible; therefore, opening up the blood and lymph spaces by incisions is not advisable; the adoption of the expectant plan of treatment offers the best results.

Muskett, in South Africa, has treated fifty cases, without fatal result, by the expectant method combined with the use of powdered ipecac, administered both internally and locally. Powdered ipecac mixed with water to the consistency of cream is applied locally and five grains of the powder with an eighth of a grain of morphine is given internally every four hours.

Quite recently specific treatment by the use of anti-anthrax serum (Sclavo's) has been introduced, and the reports from its use are very favorable; forty cubic centimetres are given subcutaneously, or intravenously if the case is urgent, and the injection is repeated after a day or two if necessary. The serum is obtained from the ass which is subjected to both active and passive immunization and after a period of about two years furnishes a sufficiently strong serum; it is prepared by Professor Sclavo in the pathological laboratory of the University of Siena. It is claimed for the serum that it is harmless, that no case treated by it early terminates fatally, and that the beneficial effects are manifest in a few hours. In nearly all cases the injection is followed shortly by a considerable rise in temperature (even to 105° F.), but this rise is a favorable sign and is followed by general improvement. As to the mode of action of the serum we are in the dark; it is evidently very different from that of the antitoxic sera of diphtheria and tetanus.

The general mortality for anthrax has heretofore been about twenty-five per cent; statistics of cases treated with Sclavo's serum show a reduction of mortality to about six per cent, but the advocates of this method claim that this by no means represents the full value of the method, as the cases treated were only those of the most severe type.

Glanders.—Glanders or rather that form of the disease known as *farcy*,

usually results from an infection of a wound of the skin with the *Bacillus mallei* by contact with material from another case of glanders. Even laboratory infections have occurred in this way, and in this sense farcy might properly be considered under the head of poisoned wounds. As the subject is, however, fully considered elsewhere, only a word will be said here as to prophylaxis in the human being.

All those, including laboratory workers, whose occupation brings them in contact with glandered animals or materials, should exercise great caution not to allow infected matter to come in touch with an abrasion or wound of any kind; but if such contact should unfortunately occur, the wound should be promptly cut out or thoroughly cauterized and covered with an antiseptic dressing, after which the development of the earliest symptoms of infection should be carefully looked for.

Actinomycosis.—While this subject is fully discussed elsewhere in this work, the infection of actinomycosis is so frequently introduced into the system through wounds of the skin that it is necessary to consider the disease here from that point of view. There is no doubt, too, that actinomycosis is much more frequent than is commonly supposed, and is often erroneously diagnosed, especially as a syphilitic or as a tuberculous affection. Those surgeons who regularly examine microscopically the pus from abscesses and sinuses will be more apt to meet with the disease than those who do not.

In cattle a very large percentage of the actinomycotic growths are in the neighborhood of the jaw; and even in man the lesion occurs in that neighborhood in about fifty per cent of all cases. These facts point to infection through food or something else taken into the mouth, and, as the fungus grows upon grass and grains, the method of inoculation is easily explained. Through some small lesion of the mucous membrane about a tooth, or perhaps from the penetration of the spike of a barbed grain, the epiphyte is introduced. Indeed, experience shows that a large majority of the cases occur in those who have to do with grain, especially countrymen, stablemen, and those engaged in similar occupations. But it is with the smaller percentage of cases, viz., those individuals who are infected through skin wounds, that we have to do here.

Mueller (E.) records a case where a woman, who ran a splinter into her hand, developed in the scar, two years later, a swelling which was found to be actinomycotic; and, on examination, a small sliver of wood was found in the centre of the mass.

Partsch (K.) reported a case where the actinomycosis developed in the scar of an operation wound, the infectious material having apparently been introduced on the surgical instruments used in the operation.

Kopfstein relates the case of a woman who cut her hand, and a few days later infected it with actinomyces while binding corn. That the infection took

place in this manner was inferred from the fact that the disease developed at the site of the cut.

Wagner (Carl) reported the case of a young physician who infected himself by inadvertently touching his nose after evacuating an actinomycotic abscess and before he had disinfected his hands. He succumbed soon afterward to an acute attack of the disease.

These and many other recorded cases prove that infection through wounds not infrequently occurs, although the disease does not always develop at the site of the inoculation.

As no means have yet been discovered by which we may learn that infection has occurred until an actual actinomycotic growth makes its appearance, it is not possible to institute any special prophylatic treatment; and the treatment of the disease itself is given *in extenso* in an earlier article in the preceding volume.

Poisoned Wounds Inflicted by the Implements of Warfare.—The poison of these wounds is, as already stated, of a dual nature—sometimes chemical, at other times bacillary, and in still other instances a mixture of both.

In gunshot wounds the poison, when present, is of a microbic nature, while in the wounds inflicted by the more ancient cutting and piercing weapons the poison is either chemical, microbic, or of a mixed nature.

The practice of poisoning the points of such weapons as arrows, spears, lances, knives, etc., is known to have been common among the European nations of the earliest times and exists to-day among primitive races of mankind everywhere. The points and edges of such weapons are specially grooved and bevelled for the reception of the poison, and many of them are so constructed as to break off in the wound or to render their extraction difficult. The practice was general among the Franks, Vandals, and Scythians, and later among the Spaniards, so recently as the time of Philip III. Among the Vandals, who principally used aconite, a small fine came to be imposed as a penalty for the use of poison. The Scythians used the venom of snakes as well as their bile and blood; the Spaniards used a poison prepared from the root of hellebore.

In some experiments made by Ledantec upon the arrow poison used by the natives of New Caledonia it was found to contain the bacilli of tetanus and also frequently those of malignant œdema; both these organisms being probably present in the mud of the crab holes in which the arrow points are dipped in the course of their preparation. In this country the Apache Indians dip their arrow points in a mixture obtained by grinding the heads of rattlesnakes with pieces of deer liver, the whole having been allowed to decompose. The Moquis prepare their poison by irritating a rattlesnake to such a point that it bites itself, the arrow points being then dipped in the escaping blood; in other cases a ground-up mixture of the bodies of bees and red ants is used for the purpose. The Lipans plunge their arrow points in the menstrual blood of a woman, while the

Comanches use the juice of the Yucca or Spanish bayonet. The Negritos of the Philippine Islands are said to use a powerful heart depressant obtained from the bark of a tree called by them *abuhab*, the scientific name for which is *Rabulaisia philipinensis*.

The Indians of the Orinoco and Amazon regions use curare. In the East Indies cardiac depressants are used, while in the South Sea Islands a poison of the nature of strychnine is employed. Other agencies used are hellebore, aconite, and other vegetable extracts, while substances containing the infections of anthrax, tetanus, and malignant œdema have also been employed.

After the adoption of modern firearms the practice of poisoning missiles became less frequent. Nevertheless, the question as to whether the wounds inflicted by such missiles should or should not be considered poisoned or infected has caused much discussion, and has been largely a matter of opinion until our modern bacteriologic technique made it possible to settle the question definitely —an achievement which has been accomplished chiefly through the carefully conducted experiments of Major Louis A. La Garde, surgeon, U. S. Army.

Major La Garde found that in the process of manufacture of ammunition the methods used were such as practically to sterilize the various materials employed except the wads. These latter are of two classes—cardboard wads and felt wads, the felt wads being made from wool, hair, soap, flour, glue, and china clay, the nature of the organic materials employed being such as to render frequent contamination probable. The black powder contained in blank cartridges and in such fireworks as firecrackers was found to have been contaminated, probably in handling. Smokeless powders are considered by La Garde to be sterile—at least at the time when they issue from the factory. His experiments also showed that the heat developed by firing and friction in the rifle barrel had no effect in sterilizing any of the components of ammunition which had been contaminated.

Another interesting observation was made by La Garde in the course of his experiments, viz., that, in firing an ordinary rifle, only about forty-three per cent of the powder is consumed in the generation of the gases, the remaining fifty-seven per cent being propelled various distances in the form of unconsumed grains producing what is commonly known as powder-burn, in which grains of powder of greater or less size lodge in the part. Black powder was found not to have any antiseptic value, while various kinds of smokeless powder were shown to have some inhibiting power upon the growth of micro-ogranisms—a power which extended only a short distance from the site at which the powder was lodged.

In a further series of experiments with specific organisms—anthrax, tetanus, colon bacillus, streptococcus, etc.—and with vegetable poisons such as curare and ricin, it was shown by La Garde that wounds could be infected with all of them by placing the poison anywhere between the point of explosion and the body—as, for example, on the powder, on the wads, on the projectile, in the gun-barrel, on the clothing, or on the skin.

Aside from such factors as the virulence of the poison and the resisting power of the individual, the character of the lesion inflicted is one of the most important factors in determining the result of infection. It has been shown that the presence of hæmatoma offers particularly favorable soil for the growth of organisms and that gunshot wounds, with their attendant conditions of hæmatoma, destruction of tissue, and necrosis from powder-burn, are still more favorable to organisms especially of the anaërobic variety, like those of tetanus. The much more favorable results of wounds inflicted by the modern small-calibre projectile, over those resulting from the old lead bullet, as regards pus-infection and tetanus, are due probably as much to the changed character of the wounds inflicted as to modern antiseptic treatment. On the other hand, the great frequency of tetanus after wounds from the "toy pistol" is due to the special character of the short-range wounds inflicted by them; these partaking, in greater or less degree, of the nature of subcutaneous injuries, with hæmatoma and powder-burn. It was thought that the tetanus organism was probably contained in the ammunition, but laboratory experiments have failed to sustain this view, and it is probable that the source of infection is the soiled skin of the hands, the hands of children being usually in constant contact with soil and dust.

The possibility of intentional criminal poisoning by means of gunshot wounds has been proven by the experiments alluded to, and this whether the poison is chemical or bacterial, animal or vegetable.

The symptoms of poisoned wounds inflicted by the implements of warfare will, of course, be those of the specific poison used. The diagnosis, in the case of a chemical poison, will depend partly upon the symptoms produced and partly upon the result of attempts to neutralize the poison by the use of appropriate antitoxins. In the case of the bacterial poisons attempts must be made to isolate the specific bacteria by cultures from all the parts involved in the course of the projectile from the weapon and ammunition to the wound.

The treatment will generally depend upon the diagnosis. In warfare, however, with people known to use poisoned weapons, the character of the poison is generally understood, or will soon be learned, and the constitutional treatment should be directed accordingly. In wounds known to be thus poisoned, any part of the weapon, such as the arrow-head, remaining in the wound should be promptly extracted, a ligature applied above the wound when practicable, the wound opened by free incision, and the poison sucked out. After as much of the poison as possible has been removed in this way, that which remains in the wound should be destroyed by the actual cautery or by the use of chemicals, as in the case of poisoning by snake-bite.

The writer is indebted, for valuable assistance in the preparation of the text, to the Mutter lecture, 1902, by Major Louis A. La Garde, surgeon, U. S. Army, on "Poisoned Wounds by the Implements of Warfare."

RABIES.

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HYDROPHOBIA.

Rabies, or hydrophobia, is a communicable disease which, in man, results generally from the bite of a dog or other animal affected with the same malady.

History.—In ancient times many authors mention rabies. The oldest trace of the disease that may be found in history is in the death of Akteon, a son of Aristeus, about thirteen centuries B.C. Later, Celsius (first century) and Cœlius Aurelianus give a detailed description of the disease. Celsius advised treating the bites inflicted by dogs, by suction and cauterization with the actual cautery; and when the symptoms of the disease appeared, he extolled immersing the patient in cold water—this method of treatment was still in use in the eighteenth century. Pliny, Galen, and Aurelianus recommended the use of caustics. We find no accurate description of the disease, however, till 1771, when Van Swieten, in his "Commentaria" drew a good clinical picture of rabies and mentioned its paralytic form. Morgagni refuted many errors made by his contemporaries, but still admitted that rabies could occur from the bite inflicted by a simply infuriated dog.

Etiology.—We now know that rabies can be communicated only by an animal affected with it; it is transmitted from animal to animal, from animal to man, and, occasionally, from man to man. No part of the globe seems to be free from it, save, probably, Australia; it is more or less endemic in certain territories, and epidemics have occurred from time to time. They have been traced as far back as the year 1271 in Europe and 1770 in America. In 1779 there was an epidemic in Philadelphia, and in 1873 one in New York and other parts of the United States. The disease is much less prevalent in this country than abroad. The most frequent source of infection is the dog, although all mammals are susceptible to the disease. Thus, persons have been bitten by rabid cats, horses, cattle, pigs, rats, wolves, foxes, skunks, etc.

The disease is usually transmitted through a bite, the danger of which depends upon the depth, the dimensions, and the location. But infection may take place through other channels. Of course, any wound, whether fresh or in the process of healing, may easily be contaminated by the rabic virus. It has very recently been demonstrated (Remlinger) that freshly shaven skin allows the penetration of the virus—a fact which is of great practical importance in cases where a person's face has been licked by a suspected animal.

It was believed, until a few years ago, that healthy mucous membranes were an efficient barrier to the rabic virus. At the present time, however, we must except the conjunctiva and the nasal mucous membrane. In fact the latter offers a very convenient channel of infection in experimental rabies—with rabbits, for instance, for diagnostic purposes.

The proportion of persons who, after being bitten by rabid animals, develop hydrophobia has been variously estimated. Tardieu and Bouley, in France, collected 855 cases, of which 399, or 46.6 per cent, died. Generally speaking, the more numerous and the deeper the wounds, the greater is the danger. Furthermore, statistics show that the mortality is greater when the bites are inflicted on bare parts. It is easy to conceive that clothing prevents to a certain extent the introduction of the virus, or, at least, reduces greatly the quantity that reaches the wound. The nerve supply of the wounded part plays also a very important rôle. Thus, face bites are the most dangerous, owing to the fact that the virus reaches rapidly the medulla through the cranial nerves. Bites on the finger tips are next in importance. Statistics show that about 90 per cent of the bites inflicted upon the face result fatally. On other parts of the body the bites show the following percentages of fatality: On the hands and wrists, 65 to 70 per cent; on the arms, 30 to 35 per cent; on the lower limbs, 20 to 25 per cent; on the trunk, 5 to 10 per cent.

Besides infection through bites, it must be borne in mind that inoculation of the virus can readily take place through scratches made by the claws of rabid animals. When, for instance, cats are affected, they are particularly dangerous on account of the many scratches they may inflict with their claws when these are contaminated with saliva.

Pathological Anatomy.—The gross lesions of rabies show nothing pathognomonic. The chief ones are found in the *central nervous system.*

Macroscopically, there are evidences of hyperæmia and hemorrhage; there is more or less extravasation in the pia mater; the meninges are often œdematous. The brain sometimes shows areas of softening. In the medulla and spinal cord there are foci of softening in the gray matter, in both the anterior and the posterior horns; the white matter shows striæ of degeneration in Goll's and Burdach's columns. These lesions predominate in the cervical portion when infection takes place through a wound on the upper limbs. The lumbar portion of the cord is affected when the wound is on the lower limbs.

Microscopically, the most important brain lesions are found in Ammon's horn, where there is an abundant migration of leucocytes from the capillaries, and the nerve cells of this region show various forms of degeneration.

In the medulla and spinal cord the lesions have been compared by Schaffer to those of an acute myelitis, more marked in the gray than in the white matter. The most constant lesions are found in the gray substance around the central canal and in the motor nuclei of the medulla and cord. They consist of small

hemorrhages and an accumulation of embryonic cells—of perithelial or migratory origin—about the blood-vessels; there are a proliferation of small cells around the ganglion cells, and a degeneration of the latter with frequent disappearance of the nucleus; the neurons often contain pigment and are invaded by small round cells—usually mononuclear, rarely polynuclear—which fill up the pericellular lymphatic spaces, thus forming small nodules which have been called "rabic nodules" or "Babès tubercles."

Golgi, Germano, and Capobianco studied more especially the ganglion cells themselves, and they showed that the alterations of the nucleus partook of the nature of a karyolysis. These lesions may be observed in the first period of the disease. Furthermore, they showed that the shape and structure of the neurons are modified in different ways. For example, in the brain, medulla, and cord the cells are vacuolated, the bodies of the cells and their processes being atrophied. The same lesions are to be found in Purkinje's cells of the cerebellar cortex. In the later stages of the disease, the neurons are the seat of granular degeneration, and there is more or less complete chromatolysis.

The above lesions, however, are not pathognomonic; they are similar to those found in various intoxications. In 1900 Van Gehuchten and Nelis announced the discovery of lesions apparently specific, if not in nature, at least in localization. They are found in the cerebro-spinal and sympathetic ganglia. They consist of a proliferation of the cells of the endothelial capsules so pronounced as to fill up, more or less completely, the spaces between the capsules and the ganglion cells; the latter showing various lesions of their protoplasm and nucleus, such as chromatolysis, alteration in shape and position of the nucleus, or even its entire disappearance. Some of the cells are completely destroyed, and their spaces are filled by small round cells. The most vulnerable of the ganglia is that of the vagus, which is usually selected for the histological diagnosis. These lesions are so constant and characteristic that their presence in a case which has shown the usual symptoms of rabies is sufficient to affirm the diagnosis. They are not absolutely specific, as they have been observed in ascending neuritis, in diabetes insipidus, in a case of diphtheria, in chronic alcoholism, and in a case of syphilis of two years' standing in which, a few months before death, there were paralysis of certain muscles of the face and of the lower limbs and some disturbances of the senses of touch, heat, and pain. Van Gehuchten held that these lesions were caused by a special action of the rabic virus on the cells of the pericellular endothelial capsules. He thought that the intense proliferation of these cells crowded the ganglion cells and finally destroyed them. Metchnikoff and his school, however, believe that the nerve cells are first affected by the rabic toxin, as is the case with other toxins, and that the other lesions are the result of a phagocytic process. Their theory is as follows: Normally, the nerve cells and their capsules, as well as the neuroglia, are in a state of equilibrium permitting the proper functions of the nobler

cell. But, as soon as the latter is affected, the equilibrium is broken; the neuroglia cells, the wandering cells, and others begin to proliferate, and their activity is exerted against the diseased cell which, if death does not occur too early, is, sooner or later, replaced by smaller cells. It is a real struggle between the nerve cells affected by the toxin and the neighboring phagocytes, which, in certain cases, finally take the place of the nerve cells.

Next to the nervous system, the *salivary glands* are most constantly affected. The submaxillary and sublingual glands are always intensely congested; the parotid gland is sometimes unchanged. Microscopically, it is seen that the capillaries are over-filled with blood; numerous round cells surround the blood-vessels, salivary ducts, and nerves; the connective tissue is œdematous; the epithelium of the alveoli is opaque and granular. At various points accumulations of leucocytes form small purulent foci. On the inferior surface of the tongue, near the base, are sometimes seen small vesico-pustules, known as lyssa. They are caused by the accumulation of the secretions from the obstructed glandular ducts. Marochetti believed that these pustules contained the virus of the disease; hence the name of "*lyssa*" which was given to it—a name which is still in use in Germany.

The *respiratory* and *digestive* mucous membranes show some congestion due to the terminal asphyxia.

The *kidneys* may be the seat of a diffuse parenchymatous nephritis; the urine sometimes contains albumin, and sugar is present in many cases.

Examination of the *blood* shows a marked polynuclear leucocytosis.

The Rabic Virus.—Of more practical importance than the pathology of the disease is some knowledge regarding its virus. Clinically, it is universally known that the virus is present in the saliva of rabid animals, and it is generally through the saliva that wounds become infected. It is of interest to know at what period of the disease the virus appears in the saliva of rabid animals. In a long series of experiments, Roux and Nocard found that the virus may be present in the saliva of a rabid dog as long as three days before the animal shows any symptoms of the disease. Pampoukis reported the case of a person who died of rabies, and who was bitten by a dog eight days before it showed the first symptoms of the disease. Zaccaria related the case of a dog which, bitten by another dog thirteen days before the latter showed any symptoms of rabies, developed the disease.

As to the presence of the virus in the saliva of human beings affected with rabies, there is some uncertainty. A few cases are on record in which the disease was transmitted from man to man through the saliva. Magendie and Breschet, in 1813, inoculated two dogs with the saliva of a man who had died of rabies; one died of the disease. A few years ago Bardach made similar tests, with some positive results. More recently, Bertarelli and Volpino (1903) inoculated twenty rabbits with the saliva and with an emulsion of the parotid,

submaxillary, and sublingual glands of a child who had died of rabies: the results were entirely negative. Remlinger (1904) inoculated eight rabbits with the filtered saliva of two men who had developed rabies twenty-seven days after being bitten by a rabid wolf: none died. Two rabbits inoculated with the unfiltered saliva were well two months after the injection.

The virus has been demonstrated in the lachrymal glands (Bombici), the suprarenal capsules, and the pancreas (Bertarelli and Volpino in the case mentioned above).

The *mammary glands* may contain the virus. As to the milk, clinical observations are contradictory, and laboratory experiments have given different results. It may be said that the virus is rarely present in the milk of rabid females.

The transmission of the virus *through the placenta*, from mother to fœtus, is uncertain. Lafosse and Canillac have seen rabies appear in calves born from rabid cows. Kolessnikoff has observed one case in the human being. Perroncito and Carita had an equal number of positive and negative results. Loir (1903) noted positive results in the rabbit.

Until recently, it was conceded that the blood of rabid animals was never virulent. However, Hertwig had stated that it could contain some virus. Lafosse was able to demonstrate this fact in one case only. Later, after numerous experiments made in Pasteur's laboratory, it was concluded that the blood was not virulent, and that, in every instance in which a positive result had been attained after inoculation with blood, it was through accidental contamination. Recently, however, A. Marie (1904), in a series of twenty experiments, succeeded twice in demonstrating the presence of the virus in the blood of animals affected with rabies: once in a guinea-pig and once in a rabbit. From these results, obtained by such a thorough and painstaking investigator, it must be admitted that, in rare cases, the blood of rabid animals may contain enough virus to cause infection. On the other hand, the lymph, the liver, the spleen, the urine, and the spermatic fluid are never virulent. Muscular tissues contain small quantities of virus owing to the presence of nerves and nerve endings.

Inasmuch as the virus is not usually found in the blood, the question has arisen as to how it was propagated through the system. In 1879 Duboué advanced the theory that the rabic virus travelled through the nerves. In 1889 Di Vestea and Zagari proved it experimentally. Roux demonstrated that the virus follows the nerves of the bitten limb to the nerve centres, and thence follows down the nerves of the opposite limb. It is possible that some of the virus follows the small lymphatics accompanying the nerves. The virulent glandular tissues mentioned in a previous paragraph receive their virus through their nerve supply.

It is of practical interest to know the amount of resistance which the rabic virus offers to the various physical and chemical agents:

Heat rapidly destroys it; an exposure to a temperature of 48° C. (118° F.) for five minutes renders it inert. A rabic medulla loses its virulence after having been heated for one hour at 50° C. (122° F.) or for two hours at 45° C. (113° F.).

Cold has little or no action: an exposure to −35° or −40° C. (31° or 40° F. below zero) only diminishes the virulence (Gibier, 1883).

An exposure to *sunlight* for forty hours (the temperature not exceeding 30° C.) destroys the virus. The *Roentgen rays* do not seem to have any action on the virus (Frantzius, Högyes).

The virus retains its virulence in *water* for from twenty to forty days. In neutral *glycerin* the virulence is unaltered for three or four weeks, and is still present after the lapse of ten or twelve weeks or even a longer period. A 1:1,000 solution of *bichloride of mercury* destroys immediately the virulence of its own volume of emulsion of rabic virus. A 2.5-per-cent *permanganate-of-potash* solution, in fifty-per-cent alcohol destroys the virulence of a similar emulsion in twenty-four hours. An emulsion in twenty-five-per-cent *alcohol* is still virulent after three days, but not after five days. An emulsion acidified with one or two drops of *acetic acid*, or made decidedly alkaline with a small crystal of *sodium carbonate*, is rendered inactive. A five-per-cent solution of *carbolic acid* destroys the virus in one hour; a two-per-cent solution in two hours. *Lemon juice* acts in from seven to ten minutes. *Silver nitrate* has very little effect on the virus; *chlorine* and *bromine* water destroy it rapidly. In cadavers, the virus retains its properties for a long time (from twenty to forty days).

Nature of the Virus.—Nothing is yet positively known regarding the nature of the rabic virus. Pasteur believed the disease to be caused by a germ, and because he was unable to isolate and stain it, he thought it was too small to be observed with the usual means. At different times some investigators believed they had found the specific microbe of the disease. Gibier, Fol, and Dowsdevel described small granulations which they found in emulsions of rabic nervous substance and in the sections of the medulla and spinal cord. These were probably granules from the protoplasm and nuclei of the degenerated cells. Bruschettini found a short bacillus which he succeeded in cultivating on a lecithin-gelatin medium, and in broth made with cerebral matter to which glucose and glycerin were added. The cultures injected subdurally killed rabbits in from five to eight days with symptoms of paralytic rabies. Investigations carried on at the Institut Pasteur, in Paris, disclosed the presence of the same bacillus in the central nervous system of non-rabid rabbits.

Recently (1903) an Italian investigator, Negri, found a peculiar structure in the central nervous system of mammals which had died of rabies, and suggested that it might be the specific parasite. He described protoplasmic inclusions which may be found in the pyramidal cells of the horn of Ammon, in Pur-

kinje's cells of the cerebellum, in the pyramidal cells of the cortex, and sparingly in the pons, the medulla, the spinal cord, and the various ganglia. These inclusions, according to Negri, are not found in the nervous systems of healthy subjects or in individuals that die of other diseases. He regards them as the specific protozoön of rabies. These bodies, which are stained red by Mann's method (methylene blue and eosin), are spherical, elliptical, or pyriform in shape; their size varies from 1 or 1.5 μ to 10, 12, or 15 μ in diameter; those which are elliptical may be as long as 22 μ and 6.5 μ wide. They consist of a non-granular, homogeneous, hyaline mass inside of which are observed light bodies resembling vacuoles. Under high magnification it is seen that some of these light bodies are surrounded by a ring of darker color, seemingly formed by a concentration of the hyaline mass; they contain a small granule, centrally located—sometimes two or three, or even a larger number. The bodies are found within the protoplasm of the nerve cells and sometimes in the processes. According to Negri, they are more numerous and of a larger size in cases of rabies with a long period of incubation. (Plate XIX.)

It is now a well-established fact that the presence of Negri's bodies is pathognomonic of rabies. Daddi, Volpino, Luzzani and Macchi, Negri, d'Amato have collected (to January, 1905) 463 cases of rabies in animals (dogs, cats, and rabbits), in all of which they were present. In a series of 93 cases investigated for this special purpose, Abba and Bormans found the bodies in 58 cases; the biological test corroborated the diagnosis, and was negative in the 35 cases in which the bodies were absent.

In several cases of human rabies the bodies were readily found: Negri, 1 case; Daddi, 3 cases; Pace, 4 cases; Bertarelli and Volpino, 1 case; Luzzani, 1 case; C. Fisch (St. Louis), 5 cases; the writer, 1 case. Nevertheless, we do not agree with Negri and some of his followers in accepting these bodies as the specific protozoön of rabies. The objections which may be raised against this claim are numerous. They are:

First.—The bodies are found mostly in the various parts of the central nervous system which we have already enumerated, and where the rabic virus is present in rather small quantities. On the other hand, the bodies are absent or extremely scarce in the medulla and the pons, which are the most virulent portions of the central nervous system.

Second.—The rabic virus—or microbe—is capable of passing through the Berkefeld filter, bougies V, N, and W. This proves Pasteur's hypothesis, that the specific organism of rabies is extremely small. Negri's "protozoön" could not go through the same filter, although Celli and De Blasi contend that, if the larger and medium-sized bodies may be stopped by the bougies, the smallest forms may pass through.

Third.—The rabic virus, as previously stated, is easily destroyed at relatively low temperatures (45° C.), whereas protozoa are not. It has been shown that

EXPLANATION OF PLATE XIX.

FIGS. 1, 2, 3, and 4.—Cells from Ammon's Horn of the Dog. Oil immersion $\frac{1}{12}$, ocular 3. Stain: Unna's blue and eosin (Frothingham). *a*, Nucleolus; *b*, Negri's bodies.

FIGS. 5 and 6.—Cells from Ammon's Horn of the Dog. Oil immersion $\frac{1}{12}$, ocular 3. Stain: eosin and Loeffler's alkaline methylene blue.

FIG. 7.—Extracellular Negri Body from the same Preparation as that Shown in Figs. 5 and 6. Oil immersion $\frac{1}{12}$, ocular 3.

NEGRI BODIES

(FROM DR. LANGDON FROTHINGHAM, IN *Journal of Medical Research*, BOSTON, MASS.)

the extremely small micro-organisms which have been discovered within the last few years offer very little resistance to heat. Thus, the blood of yellow-fever patients loses its virulence after being heated to 55° C. for ten minutes (Reed and Carroll), or for five minutes (Marchoux and Simond). The virulence of the lymph in aphthous fever disappears after an exposure to 50° C. for fifteen minutes. A temperature of 52° C. sterilizes the plague virus in one-half of an hour.

Fourth.—If an emulsion of rabic nervous substance is centrifuged and tested at different intervals, it is found that the superficial layer of liquid is still virulent after forty-five minutes; it is no longer so after one hour (Remlinger). This slow action of the centrifuge is in favor of extremely minute dimensions of the organism and against the protozoön theory.

Fifth.—In rabbits inoculated subdurally with rabic virus, the medulla is often virulent three days after inoculation and always so after the fourth day (Remlinger). This extremely rapid diffusion of the rabic virus through the nervous system is another factor against the possibility of a protozoön as the pathogenic agent of the disease.

Sixth.—The Negri bodies have never been found in the saliva of rabid animals.

C. Fisch, who for the last two years has made a very painstaking study of the Negri bodies, asserts that they bear no relation to any other known protozoa; that the body itself is no parasite, but possibly an envelope for minute parasites enclosed in it; whether this envelope is cytoplasmic or produced by the parasite cannot be said (personal communication). Thus, the ultramicroscopic-organism hypothesis of Pasteur for the pathogenic agent of rabies seems to remain the only plausible one; in other words, we have to deal with a germ and its toxin.

On the other hand, Dr. Anna W. Williams, of the Research Laboratory of the New York Department of Health, who has made a careful study of the Negri bodies for the past year, holds that the characteristic structure and staining qualities brought out by the smear method of examination render the belief that they are protozoa almost a certainty.

Remlinger was the first scientist to announce that the rabic virus could pass through the Berkefeld filter. He was closely followed by Di Vestea and Celli and de Blasi. In further experiments, Remlinger showed that the virus could even go through bougie Berkefeld W, thus proving the extreme minuteness of the organism. However, the virus is usually stopped by bougie Chamberland F. This was observed by Gibier and myself in 1894, and demonstrates at the same time the existence of the rabic toxin. In fact, rabbits inoculated subdurally with virus filtered through Chamberland F may die with all the symptoms of paralytic rabies. The brain of these rabbits emulsified in the usual way and inoculated into other animals does not affect the latter, showing that

it did not contain the germ; the rabbits were killed by the toxin which had passed through the filter, whereas the micro-organisms themselves were retained by the bougie.

The virulence of the germ, as it exists in animals at large affected with the disease—the so-called *street virus*—may be increased or diminished under certain conditions. After a succession of transfers first from dog to rabbit, and then from rabbit to rabbit, it becomes more and more virulent for this animal. The period of incubation is gradually diminished till the rabbits die regularly in ten days. The virus has by this time become of uniform strength, and is called "fixed virus." In the above experiments of Remlinger and others, both street virus and fixed virus were used, with identical results. This shows that the micro-organism is the same; the difference is only in the degree of virulence. We know this to be the case with many other germs.

Description of the Disease.—*Period of Incubation.*—Rabies, like all infectious diseases, has a period of incubation, which, it must be said, is extremely elastic. It varies from fourteen days to several months, the average being from five to ten weeks. A few cases have been reported in which the disease appeared two years after the bite. Personally, I know of one case, observed at the New York Pasteur Institute, in which a man died one year after being bitten by a rabid dog.

The length of the period of incubation depends upon the location and nature of the bite, upon the quantity of virus introduced into the wound and its degree of virulence, and upon the condition of the subject. The shorter periods of incubation are observed after bites on the face. In these cases the virus has but a short distance to travel to reach the nerve centres. All conditions depressing the nervous system have a tendency to shorten the period of incubation. On the other hand, it is quite possible that, under favorable conditions, the virus may remain latent for a long time after its introduction in the system and be finally destroyed. Pace, of Naples, recently found the virus *in the cauterized wound* of a man dying of rabies thirty-three days after being bitten. It has often been observed, in the different anti-rabic institutes, that rabbits inoculated with fixed virus, and which had apparently escaped from the disease, would suddenly develop all the symptoms of rabies, and die after being exposed to severe cold or after being insufficiently fed. Such conditions may be met with in human beings.

Symptoms.—The disease occurs in two forms: the furious form, and the paralytic form.

The *furious form* may be divided into three stages: the prodromal, the stage of excitement, and the paralytic stage.

The *prodromal stage* is characterized by nervous manifestations: the patient is melancholic, sad, indifferent to his surroundings; he prefers solitude; at times he feels an imperative desire to exercise, and finds relief in taking a long

walk. Headache is almost invariably present, being most intense in cases of bites on the face. Sleep is always broken by sudden awakenings and nightmares; this symptom being never absent, even in children. In patients who are conscious of their trouble and its dangers, the cerebral manifestations are still more marked. In some cases the period of melancholia is replaced by unusual manifestations of cheerfulness and exuberance, sometimes bordering on hysteria.

The prodromal stage lasts for from forty-eight hours to five or six days. In one case, that of a child, Roux noticed uneasiness and sadness three weeks after the bite, whereas the first symptoms of rabies did not appear till three months later.

It is very probable that the beginning of this stage coincides with the first appearance of the virus in the brain. In a series of experiments made recently, Remlinger found that the nerve centres of animals inoculated subcutaneously with fixed virus were virulent eleven and twelve days before the death of the animal, death occurring eighteen or twenty days after the inoculation. It is logical to suppose that in a man bitten by a rabid dog the nerve centres are virulent at a much earlier period than was formerly thought to be the case. *Pain in the bitten part* is often an early symptom, having appeared in some cases as early as fifteen days before any other symptom. The pain is lancinating, usually radiating from the cicatrix; at other times it is replaced by a feeling of numbness or cold. After a bite on the hand, for instance, the pain is first felt in the spot where the bite was inflicted, whether there be any visible cicatrix or not; then it gradually extends into the wrist, the forearm, the arm, the shoulder, and the side of the neck.

Then come symptoms due to the involvement of the medulla, and the *period of excitement*, or *hydrophobic stage*, begins. Respiration becomes irregular and seems difficult, being interrupted by deep inspirations; the pulse is accelerated; vomiting sometimes occurs; the pupils are dilated. Difficulty in deglutition is, however, the one symptom which usually attracts the attention of the patient and those near him. It appears more or less suddenly and much to the surprise of the unfortunate subject, who has often forgotten by this time that he ever was bitten, and is in utter ignorance as to the nature of his ailment. In several cases, men have told me that the first intimation they had that something was wrong was in the difficulty they experienced in "taking a drink." They could not account for it, would make repeated trials, and then conclude that "if they could not get down a drink of whiskey they must be in pretty bad shape." In attempting to eat or drink, the patient feels a sort or constriction of the pharynx. It is transitory, but reappears at each attempt to swallow. The facial expression denotes the painful sensation which is felt. On being offered a glass of water or other liquid, the patient, although thirsty, at first refuses. Then, if he can be persuaded to try, he spasmodically extends the arm to get

hold of the glass; the eyes become fixed; the jaws tighten; the nares are dilated. The glass is brought to the mouth by jerks, and, as it gets near, the patient, trembling, eagerly leans toward it, and, while making an attempt to drink—whether he be successful or not—the respiratory spasm is brought on. The head is raised, slightly thrown back, and three or four short, jerky inspirations are made; the facial and neck muscles are rigid; respiration stops. Then there is a sigh and the patient is calm till the next crisis occurs. This is brought on by the sight of a liquid, by the noise made by running water, by a sudden noise of any character, by a bright light suddenly brought before the patient's eyes, or, finally, by a draught of air blowing on the patient's face—this latter event invariably producing a spasm. There is general hyperæsthesia; the reflexes are exaggerated; restlessness is marked. The patient may get up from his bed, strike his head against the wall, and thus inflict upon himself quite severe wounds without apparent suffering. Rarely have rabid persons become aggressive or have attempted to bite except when put under restraint; on the contrary, they usually warn their attendants of an oncoming attack and beg them to remain away, fearing to harm them. They have no desire to talk. When asked a question they seem reluctant about answering. When they do reply, a slight respiratory spasm precedes the first words, and the sentences are abrupt and interrupted by short inspirations. The voice is often husky, and when the patients are excited and attempt to talk loudly, they emit a peculiar sound which has led to the popular saying that they "bark like a dog."

Death sometimes occurs at this stage, but, as a rule, the disease goes on into the *paralytic stage*. Consciousness gradually disappears, after alternating periods of perfect lucidity and hallucination. The crises of spasms become less frequent and weaker. The ability to swallow sometimes returns, and small quantities of food may be taken, but the patient becomes weak. Certain groups of muscles are paralyzed; ataxic movements may be observed. Salivation is profuse, the saliva being usually thick and ropy. The body temperature, which is but little above normal during the stage of excitement, rapidly rises to 38° or 39° C. (100°–102° F.) or even higher. (I had occasion to observe one case in which the temperature remained above 102° F. for three days, and rose to 105° F. a few hours before death.) The pulse is feeble and rapid—from 120 to 140. Facial paralysis, or hemiplegia, or ophthalmoplegia, or paraplegia, precedes the final collapse. This stage is often very short and rarely lasts longer than twelve hours.

In rare cases of furious rabies the prodromal stage may be absent and the disease may begin suddenly with the period of excitement. This is more likely to occur when the development of the disease is hastened through some accidental cause such as a violent emotion, exposure to cold, excessive exertion, etc.

The *paralytic form* of rabies differs from the foregoing in the more or less total absence of the stage of excitement. The prodromal stage is the same

as in the furious form. The first symptom of the disease is usually a sensation of numbness and heaviness in the bitten limb. There is pain in the site of the wound, and the muscles are the seat of fibrillary contractions. Then the limb becomes weak and clumsy, and its movements are ataxic. Sometimes the paralysis does not begin in the bitten part. The first symptoms then consist of violent pains confined at first to the lower limbs and then extending to the trunk. At the same time there are numbness and weakness of the limbs, and movements become impossible. Whatever may be the first symptoms of the disease, the paralysis is usually ascending. From the limbs it extends to the trunk, then to the bladder, rectum, and intestines. It may reach the muscles of the pharynx and often becomes general before death takes place.

The average duration of the disease is from three to four days. It may be as short as two days or as long as eight days. The paralytic always lasts longer than the furious form of the disease.

Diagnosis.—The clinical diagnosis of rabies is easily made. One symptom is pathognomonic—that is, the pharyngeal and respiratory spasm caused by a slight draught of air. I usually bring out this symptom by gently blowing on the patient's face, while his attention is attracted by a third person or by conversation. Even if the patient is talking and in the midst of a sentence, the characteristic spasm occurs and forces him to stop. The facial expression is quite characteristic and never to be forgotten.

Rabies must, however, be differentiated from hysteria, tetanus, lyssophobia, delirium tremens, and poisoning by stramonium or by belladonna.

In *tetanus* the spasms are tonic rather than convulsive; the mental state and facial expression differ from what is observed in rabies; and the contractures of the jaws and limbs are quite characteristic of the disease.

In *hysteria* the reflex contractions brought on by cutaneous stimuli are never as intense as those of the rabic spasm.

Lyssophobia or *imaginary hydrophobia* occurs only in neuropathic persons; it is amenable to treatment and its symptoms usually last for so long a time that no mistake can be made.

In the other affections, the history of the case and the characteristic symptoms peculiar to each are usually sufficient to prevent error; furthermore, the absence of the pathognomonic symptom mentioned above will eliminate rabies.

The examination of the blood in this disease is of little practical value, inasmuch as nothing abnormal may be found up to within two or three days before death occurs. At that time there is a slight polynuclear hyperleucocytosis. This increases with the progress of the disease, so that a few hours before death the leucocyte count may be over 20,000; and it reaches its maximum at the time of death, the percentage of polynuclear leucocytes being as high as 85. This is constant (I have observed it in a series of fifteen consecutive cases), and the

absence of this polynuclear leucocytosis would have a negative value in making a diagnosis.

Treatment.—(1) *Local.*—Wounds inflicted by rabid animals—or animals supposed to be rabid—should be treated like any other infected wounds. Bleeding should be encouraged, as a free flow of blood may carry off with it a great part of the virus. Then the wound should be thoroughly washed with any good antiseptic solution. The newer colloidal silver or silver-salt preparations are to be preferred, inasmuch as their solutions do not coagulate albumin, they penetrate into the tissues, and they may destroy the greater part of the virus introduced into the wound. If these preparations are not at hand, the compound tincture of iodine makes a very efficient application. It is rather painful, but the wound may first be anæsthetized with a weak cocaine solution or with a few crystals of chloretone. A four-per-cent solution of carbolic acid may be used for very superficial wounds, but for deep ones it is too lacking in penetrating power. In the absence of any of the usual antiseptics, pure lemon juice may be tried. It is active "*in vitro*," but I have had no experience with it clinically, and cannot vouch for its usefulness. Cauterization of the wound, which is the treatment handed down to us from the first century, and is, in the popular mind, the necessary accompaniment of a dog bite, is still greatly in favor. Personally, I am very much opposed to it: *it can never be relied upon.* It is true, it has been shown that *immediate* cauterization with the cautery (actual or thermo-), or with fuming nitric acid, will often destroy all the virus inoculated. If it does not afford an absolute safeguard, it will tend to increase the length of the period of incubation, and this is important, if the patient cannot reach an antirabic institute within a short time. If the wound cannot be treated in this way within one hour, it is much better to treat it antiseptically. Indeed, who would think, nowadays, of using the cautery, or nitric acid, in a wound which had been infected with any of the known bacteria?

As may be gathered from what has been said on the pathology of rabies and the nature of its virus, we know that we have to deal with a germ and its toxin. Hence the rationale of treating wounds infected by the rabic virus in precisely the same manner as we would treat any other infected wounds. Furthermore, I consider cauterization as being dangerous, as it usually gives the victim a false sense of security. An experience of fifteen years in an antirabic institute is sufficient to teach one to be cautious in dealing with a disease which cannot be treated except prophylactically, and in which, when the first symptoms have appeared, the mortality may be said to be one hundred per cent.

One word with regard to nitrate of silver, which is so often used for cauterizing. It is worse than useless, as it almost invariably retards the healing of wounds which, treated in the ordinary way, would promptly get well.

(2) *General.*—When the first symptoms of rabies have appeared, all that can be done is to relieve the patient's sufferings as much as possible. Any exciting

cause of the spasms should be avoided. Hence the patient should be placed in a darkened room, free from draughts, and as far removed from any noise as possible. Visitors should not be allowed in the room. During the stage of excitement, repeated doses of hyoscine hydrobromate, in hypodermatic injections, should be given. Hyoscine seems to be the most efficient drug at our disposal for quieting rabic patients. Chloral and morphine have little or no effect. Nutrient enemata may be given; also normal salt solution to relieve thirst. However, the least the patient is disturbed, the better. The patient's saliva should be carefully collected and sterilized; all clothes contaminated with it should be boiled or exposed to sunlight in the open air for several days. During the paralytic stage, whenever the ability to swallow reappears, fluid food may be given and will usually prove agreeable to the patient.

(3) *Vaccination.*—Inasmuch as rabies may be considered an invariably fatal disease, its real treatment is necessarily a preventive one.

On February 24th, 1884, at a meeting of the *Académie des Sciences*, Pasteur announced that he had immunized dogs against rabies by means of a series of inoculations made with virus of different strengths. He had succeeded in attenuating the virulence of the virus of street rabies by successive transfers from monkey to monkey. After a few transfers through these animals, the virus obtained from them would kill rabbits in twenty, twenty-five, and thirty days instead of from twelve to thirteen days, the usual length of time. In vaccinating dogs Pasteur would begin with the medulla of a rabbit inoculated with monkey virus of such attenuated strength that intravenous injections of an emulsion of this rabbit's medulla would not cause the death of other rabbits when injected into them subdurally. However, this method of vaccination was too complex.

While Pasteur was prosecuting with success his efforts to attenuate the virulence of the street virus, he also discovered that the virulence of this same virus could be enhanced by successive transfers from rabbit to rabbit. He found, for example, that the period of incubation, in this animal, might be shortened from the usual ten or twelve (or at times more) days to six or seven days. When virus was used that had passed through from sixty to one hundred transfers, the rabbits would invariably die ten days after a subdural inoculation. Thus, a virus of fixed strength—"fixed virus"—was obtained. In 1885, Pasteur, Chamberland, and Roux, after a long series of experiments, established the fact that the spinal cords of rabbits dead of laboratory rabies gradually lost their virulence when exposed to an even temperature in a comparatively dry atmosphere. For instance, cords thus exposed for two, three, and four days at a temperature of 23° C. still cause the death of the animals into which their emulsions are injected. After five days, the cords are still virulent, but the period of incubation of the disease in inoculated animals is somewhat lengthened. After an exposure of six days, the results vary; some animals

contracting the disease with a markedly lengthened period of incubation, while others remain well. After seven, eight, and nine days the cords are very rarely virulent, and practically never virulent after ten days.

The effect of desiccation on the rabic cords seems to be a diminution in quantity of the virus—but not a depreciation of the quality. In fact, the brain of a rabbit that had been inoculated with cord No. 6 (cord exposed to desiccation for six days) and had died of rabies in fourteen days, will, when emulsified and injected subdurally into another rabbit, cause the death of the latter in ten days.

The principle of the Pasteur method is to begin vaccination with non-virulent cords, and to proceed gradually with cords of weak virulence till finally cords of full virulence are used. Pasteur had thus discovered the fundamental principle of immunity which has since been followed in many microbic diseases with the most brilliant success. He had emitted the supposition that, besides the rabic virus, there existed a vaccinal substance the resistance of which was greater than that of the microbe itself. This he proved by vaccinating dogs by means of repeated injections of non-virulent cords. Immunity was thus obtained, but it was not absolute, whereas strong immunity may, in dogs, be acquired after a single subcutaneous injection of fixed virus of full strength. This is in accordance with our latest knowledge on problems of immunity. We know that immunity conferred by injections of the germ itself—when feasible—is much greater than that which is obtained by the injection of its toxin alone.

The Pasteur method is carried out as follows: Rabbits are inoculated intracerebrally with fixed virus. Immediately after the death of each animal, the spinal cord is removed with strict aseptic care and hung in sterilized flasks at the bottom of which have been placed a few pieces of caustic potash. The flasks are provided with a cotton stopper which allows free admission of air, and they are kept in a dark room in which the temperature is maintained as closely as possible at 23° C. (73° F.). Under these conditions the virulence of the cords gradually diminishes, so that after from twelve to fourteen days they may be used for the beginning of the series of inoculations which constitute the Pasteur treatment. The treatment was used for the first time in July, 1885. Since then it has been somewhat modified in its details, but the principle remains the same. The treatment consists of injections of an emulsion prepared by triturating small pieces of the desiccated spinal cords with a certain quantity of normal salt solution. Each patient receives daily a subcutaneous injection of from 3 to 6 c.c. of such an emulsion. On the first day of treatment, for instance, an emulsion of the cords of the twelfth and eleventh days is used—that is to say, a piece about one-half centimetre long is cut from a spinal cord which has been hanging as described above for twelve days; another piece of the same length is cut from the cord of the eleventh day. Both pieces are received in a small sterilized conical glass, and are crushed with a sterilized glass rod suit-

ably ground for that purpose. Then 6 c.c. of normal salt solution are gradually added till a homogeneous emulsion is obtained. The patient is injected subcutaneously, in each flank, with 3 c.c of the emulsion. The length of the treatment varies according to the severity of the case, and the treatment itself is somewhat modified to meet emergencies.

In ordinary cases, when bites have been inflicted on the hands or limbs and the patient comes for treatment within one week after the accident, the treatment is given during eighteen consecutive days, and the schedule observed is the following:

Day of Treatment.	Age of Cord.	Quantity of Emulsion Injected.
1st	12.11	6 c.c.
2d	10.9	6 "
3d	8.7	6 "
4th	6	6 "
5th	6	6 "
6th	5	4 "
7th	5	6 "
8th	4	4 "
9th	4	6 "
10th	3	4 "
11th	2	4 "
12th	6	6 "
13th	5	6 "
14th	4	6 "
15th	3	6 "
16th	2	6 "
17th	2	6 "
18th	2	6 "

When a delay of more than one week has occurred between the accident and the arrival of the patient at the Institute, the treatment is given during twenty-one days, according to the schedule appended below:

Day of Treatment.	Age of Cord.	Quantity of Emulsion Injected.
1st	12.11	6 c.c.
2d	10.9	6 "
3d	8.7	6 "
4th	6	6 "
5th	6	6 "
6th	5	4 "
7th	5	6 "
8th	4	4 "
9th	4	6 "
10th	3	4 "
11th	2	4 "
12th	6	6 "
13th	5	6 "
14th	4	6 "
15th	3	6 "
16th	2	6 "
17th	5	6 "
18th	4	6 "
19th	3	6 "
20th	2	6 "
21st	2	6 "

In all cases of bites on the head, and also when patients come to the Institute more than two weeks after having being bitten, the treatment is given during twenty-three days and twice each day for the first two days, and twice on the seventh and eighth days, as follows:

Day of Treatment.	Age of Cord. A.M.	Age of Cord. P.M.	Quantity of Emulsion Injected.	
1st	6	6	4 c.c.	4 c.c.
2d	5	5	4 "	4 "
3d	4		4 "	
4th	4		4 "	
5th	3		4 "	
6th	2		4 "	
7th	12.11	10.9	6 "	6 c.c.
8th	8.7	6	6 "	6 "
9th	6		6 "	
10th	5		6 "	
11th	5		6 "	
12th	4		6 "	
13th	4		6 "	
14th	3		6 "	
15th	2		6 "	
16th	2		6 "	
17th	6		6 "	
18th	5		6 "	
19th	4		6 "	
20th	4		6 "	
21st	3		6 "	
22d	2		6 "	
23d	2		6 "	

The above schedules are those followed at the New York Pasteur Institute. In Paris, the treatment is begun with the fourteenth and thirteenth day cords, and is given during from eighteen to twenty-one days, according to the cases. The special twenty-three-days formula used in New York for the last five years was adopted on account of the large percentage of cases of bites on the head and delayed cases that we are constantly called upon to treat. In fact, our statistics show that this percentage is much greater than abroad.

Several years ago Högyes, in Buda-Pesth, inaugurated a modification of the Pasteur method, and since then he has followed this modified plan with good results. Starting from Pasteur's hypothesis, that desiccation diminishes the virulence of the cords by altering the quantity of the virus and not its quality, he thought of replacing the emulsions of cords by gradual dilutions of fresh virus. The stock solution is prepared by triturating thoroughly one gram of fresh rabbit's medulla and adding gradually 100 c.c. of normal salt solution until the emulsion becomes as perfectly homogeneous as possible. This one-per-cent emulsion is used to make dilutions up to 1:10,000. The weak dilutions—1:10,000 to 1:5,000—correspond in virulence to cords 14 to 7; the stronger dilutions—1:2,000, 1:1,000, 1:500, 1:200, 1:100—correspond to the virulent cords 6 to 2. The length of treatment and the quantities of emulsion used daily are the same as in the original Pasteur method.

Serumtherapy.—If the serum of an animal vaccinated against hydrophobia according to the Pasteur method is mixed in suitable proportions with an emulsion of fixed virus or street virus, the latter is neutralized and may, with impunity, be injected subdurally into animals susceptible of developing the disease. The serum therefore possesses antirabic properties. Kraus and Kreissl have found that such is the case with the serum of persons who have received the Pasteur treatment. Inert at first, their serum acquires antirabic properties twenty days after the end of the treatment, and may retain them for a long time.

Tizzoni and Centani, and Babès have used the serum of sheep immunized against rabies in the prophylactic treatment of the disease, but the results obtained have not warranted the general adoption of their method.

Marie and Remlinger have recently made extensive experiments with the serum of sheep strongly immunized by means of repeated intravenous and subcutaneous injections of emulsions of fixed virus (Högyes method). They have demonstrated that the antirabic action of this serum is absolutely specific, and that the specific substance fixes itself on the rabic microbe.

It may be said that thus far an antirabic serum has not been obtained which can be of practical use in the treatment of hydrophobia.

Statistics.—The results of the Pasteur treatment were most gratifying from the very beginning of its application, in 1885. With the improvements which have been made from time to time upon the original method, the mortality has been gradually lowered till now it averages about half of one per cent.

The efficiency of the treatment depends upon the length of time that has elapsed between the infection and the beginning of the preventive inoculations, and also upon the location of the bite. If the patient comes too long a time after the infliction of the bite, or if the wound is near the nervous centres, the danger is the same; the virus may gradually reach the medulla before the system has been protected by the vaccinating process.

In making out the statistics, it is customary not to include the persons who die within fifteen days after the last inoculation. In fact, it must be assumed that, in individuals who show symptoms of rabies within fifteen days after the completion of the treatment, the virus had already begun to develop during the course of the injections; for we know that in animals inoculated subdurally with street virus, the symptoms of rabies usually develop about fifteen days after the inoculation. Therefore, in such cases, the treatment must have been useless because begun too late; it cannot, however, be said to be a failure inasmuch as the conditions for its efficiency were not fulfilled.

Below are given the statistics of the Institut Pasteur, Paris, from its inauguration:

Year.	Persons Treated.	Died.	Mortality Per Cent.
1886	2,671	25	0.94
1887	1,770	14	0 79
1888	1,622	9	0 55
1889	1,830	7	0 38
1890	1,540	6	0 32
1891	1,559	4	0 25
1892	1,790	4	0 22
1893	1,668	6	0.36
1894	1,387	7	0 50
1895	1,520	5	0 33
1896	1,308	4	0.30
1897	1,521	6	0 39
1898	1,465	3	0 20
1899	1,614	4	0.25
1900	1,420	4	0.35
1901	1,321	6	0.38
1902	1,105	2	0.18
1903	628	2	0.32
1904	755	3	0.39
Total.	28,494	121	Average: 0 39

In the following table may be seen the results obtained at the New York Pasteur Institute from 1890 to 1902:

Year.	Persons Treated.	Died.	Mortality Per Cent.
1890	109	0	0
1891	100	2	2
1892	104	0	0
1893	85	0	0
1894	89	1	1 12
1895	167	2	1.19
1896	236	0	0
1897	133	1	0.74
1898	125	1	0.80
1899	159	2	1.25
1900 and 1901	241	1	0.41
Total .	1,608	10	Average: 0.67

In accordance with the method adopted in Paris in making detailed statistics, patients are divided into three classes: A, B, and C.

In class A belong cases bitten by animals proved rabid by experimental inoculation, or by having caused the death of other persons or animals which they had bitten.

In class B are included cases in which the animal was proved rabid by veterinary examination.

In class C are tabulated cases in which the animal had disappeared or had been killed after having acted in such a manner as to lead one to suspect hydrophobia.

The following table shows the detailed statistics of the New York Pasteur Institute for the years 1902, 1903, 1904, and 1905:

	Bitten on the Head.			Bitten on the Hand.			Bitten on the Limbs.			Total.		
	Treated.	Died.	Mortality per cent	Treated.	Died.	Mortality per cent.	Treated.	Died.	Mortality per cent.	Treated.	Died.	Mortality per cent.
Table A.	41	0	0	134	1	0.74	68	0	0	243	1	0.41
Table B.	9	0	0	45	0	0	9	0	0	63	0	0
Table C.	29	0	0	71	0	0	76	0	0	176	0	0
	79	0	0	250	1	0.40	153	0	0	482	1	0.20

It may be seen that the percentage of deaths for the last four years is lower than the average mortality for the first twelve years. The reasons for this are:

First.—Improvements in the method of treatment which had to be adapted to the conditions met with here, which are less favorable than those encountered abroad. *Second.*—Diffusion of a better knowledge of rabies and its prevention among the medical profession and the public at large. *Third.*—Improved methods of diagnosis rendering it possible to ascertain within a short time whether an animal biting a person is rabid or not.

It may therefore not be amiss to give here a brief *résumé* of the symptoms and of the methods of diagnosis of rabies in animals:

Diagnosis of Rabies in Animals.—The diagnosis of rabies in animals may be established upon clinical symptoms corroborated by laboratory experiments.

Inasmuch as the dog is, in nine cases out of ten, the animal to be suspected of being affected with rabies, I will only consider the clinical symptoms presented by this species. The chief ones are:

1. Change in the disposition of the dog.
2. Unusual manifestation of attachment to its master.
3. Disappearance from its home for from several hours to two days.
4. Change in the bark, or total absence of barking, even on provocation.
5. Lack of appetite, difficulty in chewing and swallowing solid food.
6. Excitement and hallucinations; animal snaps at imaginary objects; may attack its own master. Excitement caused by the sight of another dog. (This stage may be absent in the dumb form of the disease.)
7. Animal eats its own bedding, tears cushions, carpets, etc.
8. Inability to eat; animal takes food in mouth, but it drops out after one or two attempts at swallowing have been made; drinking, however, is little or not at all interfered with and *there is no hydrophobia* (in the stricter sense of the term).
9. Unsteady gait which shows the beginning of paralysis of hind legs. Dilated pupils.
10. Later: paralysis of lower jaw (dropping of the jaw); general paralysis.

In other animals, the general symptoms are somewhat similar. The laboratory diagnosis of rabies is, of course, the most accurate and the one to be depended upon.

Formerly, the only safe way in which one could make a positive diagnosis was to inoculate guinea-pigs and rabbits subdurally with an emulsion prepared with a piece of the suspected animal's brain or spinal cord. It is yet the crucial test, but it is obviously too slow; the symptoms do not appear till from ten to twelve or fifteen days after the inoculation. In cases of bites on the face, it would be very imprudent to wait so long before giving the patient the benefit of the Pasteur treatment.

The microscopical examination of the cerebro-spinal ganglia, according to Van Gehuchten and Nelis' method, was a valuable addition to our means of diagnosis; with it, a result may be obtained within twenty-four hours. The technique is as follows: Fixation of the vagus ganglia in Van Gehuchten's fluid (acetic acid, 1 part; chloroform, 3 parts; absolute alcohol, 6 parts), followed by their immersion in absolute alcohol, which must be frequently changed till the reaction is no longer acid; embedding in paraffin or celloidin; staining according to Nissl's method (methylene blue), or with Delafield's hematoxylin and Van Gieson's solution. The lesions (which have been described in a previous section of this article) are always present when the animal died of rabies or was in the paralytic stage when killed, but they may be absent during the first stages of the disease; hence there is here a source of error which renders the inoculation test necessary when the lesions are not present.

Now, however, we have in Negri's discovery a very satisfactory and rapid way of making a diagnosis of rabies. In fact, Negri's bodies are almost always present in the brain of animals affected with rabies, even in the early stages.* Furthermore, and this is of great importance, they may be found in putrefied material. In a rabid brain which has undergone putrefaction, and in which every structure shows signs of disintegration, the Negri bodies alone remain unchanged and stain as in fresh specimens.

The technique of the examination is as follows: Small pieces are taken from the cerebral cortex and Ammon's horn of the suspected brain and cut up in thin slices. These are fixed in Zenker's fluid and embedded in paraffin. Sections of 5 μ in thickness, or less if possible, are cut and stained according to Mann's method (eosin and methylene blue). The bodies, when present, are stained red, and are easily distinguished within and among the blue nerve

*In a series of 147 cases Langdon Frothingham found the Negri bodies absent in twelve cases. In these cases the lesions were present in the vagus ganglia. However, in one case in which typical lesions existed in the ganglia and Negri bodies were absent, animal inoculation remained negative.

In two cases of human rabies, one observed by Dr. Fisch in St. Louis, and one at the New York Pasteur Institute by Dr. Wheeler, the Negri bodies could not be found in the brain, but were present in the brains of rabbits inoculated with pieces of the human brain.

cells. Or, the pieces of brain tissue may be hardened in alcohol and the sections stained with hematoxylin and eosin.

In this way a diagnosis may be made in less than twenty-four hours. The most simple and convenient way, however, is the smear method, which does away with embedding and section cutting. This method, advocated by Dr. Ira Van Gieson, of New York, is as follows: A small portion of Ammon's horn, say the size of a bird shot, is placed on one end of a slide; it is covered with a cover-glass, gently squeezed out with the ball of the finger, and the cover-glass shifted across the length of the slide. The smear is fixed for a few seconds in methyl alcohol and stained with any suitable dye, Giemsa's solution being one of the best. In routine practice, where a diagnosis is desired in as short a time as possible, I have adopted Van Gieson's method of staining. The stain is prepared by adding to 10 c.c. of distilled water 2 drops of a saturated alcoholic solution of rose anilin violet and 2 drops of a saturated aqueous solution of methylene blue diluted one-half with water. A few drops of the stain are poured on the smear and the slide held over the flame till steam is given off: the preparation is then rinsed in water and dried in the air. The Negri bodies take a distinctive deep crimson color, with their chromatin particles blue; the nerve cells are stained blue, the intercellular substance purplish, and the red blood cells yellowish. (See Plate XIX.)

A material advantage of this "squeeze-smear" method is that it dislocates and pulls the Negri bodies out of the neuron bodies so that they can be studied separately and without the disturbing presence of other objects in the field. Furthermore, the whole procedure of making the smear and staining as above is accomplished in a few minutes.

To resume briefly the proper course to follow when a person has been bitten by a dog or other animal suspected to be rabid:

The wound should be treated antiseptically like any other wound;

The dog, if captured alive, should be watched for several days (eight to fifteen) in order to ascertain whether it is rabid or not. If it develops symptoms strongly suspicious of rabies, it may be killed and the brain examined for Negri's bodies;

A positive diagnosis having been established, the patient should not delay in submitting to the preventive treatment.

PART XII.

INJURIES AND SURGICAL DISEASES OF BONE.

FRACTURES.

By DUNCAN EVE, M.D., Nashville, Tennessee.

I. FRACTURES IN GENERAL.

This class of injuries demands the greatest care on the part of both surgeon and patient. Fractures are of frequent occurrence among people of all ages (estimated to be one-seventh of the injuries), and, if they are not properly cared for, the consequences may be serious, not only to the subject of the accident, but also to the surgeon in charge of the case. In many instances the difficulty of making a correct diagnosis is great, and yet it is a matter of importance that the true nature of the fracture should be ascertained at the earliest moment possible, in order that the proper remedial measures may be applied without undue loss of time. An erroneous diagnosis or a failure to adopt the proper remedial measures at a sufficiently early date after the occurrence of the accident may prove disastrous to the reputation of the surgeon by causing an imperfect or a vicious union of the fractured segments of the bone, or—as has happened in rare instances—by producing a fatal issue. A thorough knowledge of the anatomical relations of the parts involved, a wide experience, practical common sense, calm judgment, and constant vigilance are the characteristics of which the surgeon who is called upon to treat fractures stands most in need. On the other hand, it is also of great importance that both the patient and his attendants should obey the surgeon's instructions implicitly.

Definition.

More than two centuries ago Richard Wiseman defined a fracture as "a solution of continuity in a bone, suddenly made, either by contusion or flexure." A better definition than this, in my judgment, is that given by Gross, viz., "a division of the bony fibres, occasioned by external violence or muscular contraction."

Varieties.

No two authors agree as to the nomenclature of fractures, but the following seems to be a practical general division sufficient for all purposes: Complete and incomplete; simple or single; double; multiple or comminuted; compound; complicated; transverse, oblique, longitudinal; serrated; punctured; gunshot; and impacted.

A *complete fracture* is one in which the line of fracture passes entirely through the length, breadth, or obliquity of the particular bone, and is subcutaneous, or with no wound extending from the surface to the bone.

An *incomplete fracture* is a partial separation of some of the bony fibres, with but slight separation of the edges, and is understood to include three conditions—a bending of the bone, a partial fracture, and a fissure. (Fig. 12.) In *bending of the bone,* although there may be but little or no appreciable solution of continuity, a certain amount of lesion is assumed to exist. This is sometimes called "interstitial fracture" or "intraperiosteal fracture." A *partial fracture*—also termed "green-stick," "hickory-stick," or "bent" fracture—is the true incomplete fracture. It occurs usually in childhood, as the result of an indirect force, and is observed particularly in subjects suffering from rickets. The bones which are generally thus broken are those of the forearm, the clavicle, and the

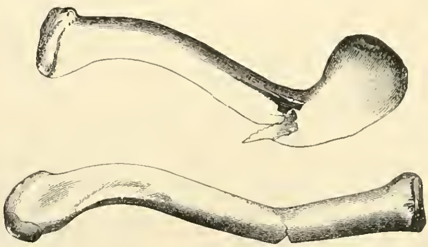


Fig. 12.—Specimens of Incomplete Fracture of the Clavicle.

ribs. A *fissure,* or the incomplete fracture observed in persons who are older and who consequently have less flexible bones, is commonly met with in bones of the skull, and in gunshot and punctured fractures of other bones.

In a *simple* or *single fracture* the bone is broken in but one place and does not communicate with the external air; *multiple* or *comminuted fractures* are those in which the bone is broken at two or more points. When a flat bone is broken in many pieces it is sometimes called an "egg-shell fracture."

A *double fracture* is one in which a bone is fractured in two places.

A *compound fracture* is a fracture in which there is an external wound that communicates, through the tissues, with the fractured part of the bone; or a fracture in which the end of the bone protrudes through the soft parts—one, therefore, in which there is an open wound that extends from the surface to the fractured bone. It is called a *primary* compound fracture when the solution of the soft parts is produced at the same time as the fracture; and a *secondary* compound fracture when the breach in the soft parts occurs after the injury, as from sloughing or ulceration, rough handling, neglect, etc. A compound fracture may be externally or internally compound, according to the location

of the wound or the spot where the end of the bone makes its appearance. For example, if the bone protrudes through the skin, the fracture is called an external compound fracture; but when it protrudes through a mucous membrane, as into the mouth, the fracture is said by some to be an internal compound fracture.

The term *complicated* is reserved for other conditions not already named. It is used when, in addition to the fracture of the bone, there is an injury of a joint, of an artery, of a vein, or of a nerve. It is usually restricted to a local condition and does not apply to a constitutional affection.

The terms *transverse, oblique,* and *longitudinal* indicate the direction of the line of fracture in relation to the long axis of the bone. A transverse fracture seldom occurs in the shaft of a long bone except in children. The cause is often direct force, while in oblique fractures the cause is usually indirect force. Gunshot injuries of a certain bone frequently produce longitudinal fractures.

Serrated or toothed fractures present angular projections like the teeth of a saw, and occur usually near the extremity of a long bone, and are not so common in the young or middle-aged as in those of more advanced life.

A *punctured fracture* is one that is caused by a sharp-pointed instrument or weapon, such as a knife, bayonet, or arrow, and is ordinarily accompanied by fissures.

Gunshot fractures are always compound, the danger depending upon the size and velocity of the missile. The special features are usually the extensive fissuring and splintering of the bone and the infection of the wound—conditions which demand prompt attention.

An *impacted fracture* is one in which one fragment is driven into another and wedged or fixed.

Fractures are sometimes classified according to location. In young persons the epiphysis is very apt to become separated from the diaphysis (*diastasis*), the conditions thus created resembling those of a real fracture. The epiphyseal cartilage, as a result of injury or in some other manner, frequently becomes prematurely ossified, interfering with the subsequent longitudinal growth of the bone. A fracture of the head of a bone almost invariably involves the articular surface, thus establishing a condition of special importance. Fractures of the neck of a bone are termed *intracapsular* when they are located wholly within the joint capsule; *extracapsular*, when they are in the immediate vicinity of the joint but outside the joint capsule; when the fracture lies partly within and partly without, it is sometimes termed a *mixed fracture*. An *intercondyloid fracture* is one that enters the joint between the condyles. The separation of an apophysis may be occasioned by direct violence from without, or by severe muscular action. *Spontaneous fracture* is an old term used in connection with pathological conditions which induce undue brittleness of bone. As such conditions may be mentioned: caries and necrosis; tumors, both benign and malignant, produc-

ing interference with nutrition of the bone by pressure; osteomalacia; osteoporosis; fragilitas ossium; osteitis deformans, etc.

Fractures are sometimes given other qualifying names, such as wedge-shaped, V-, Y-, or T-shaped, stellate or star-shaped, helicoidal, spiral or spiroidal (Fig. 13), torsion-shaped, silver-fork, by *contrecoup*, "*en bec de flute*," etc. Certain proper names are also used for designating certain fractures, as Barton's fracture and Colles' fracture at the wrist, and Pott's fracture near the ankle.

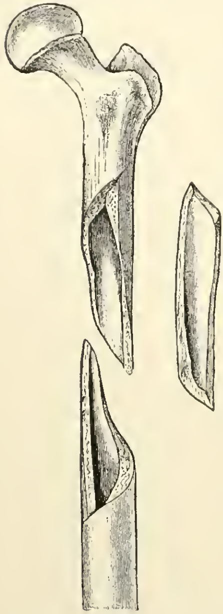


Fig. 13.—Type of Spiroid Fracture of the Femur in its Upper Third. (von Bruns.) A large shell-like detached fragment, like that shown in the picture, is found quite constantly in these fractures due to torsion.

Compound fractures are of far more serious import than simple fractures, the dangers being much greater under these circumstances than where a wound of the soft parts, similarly located, is not connected directly with the fracture. The combination of any fracture with an open wound of the overlying tissues is a serious additional danger, one not at all proportionate to the combined dangers of these two conditions existing separately but simultaneously. The possibility of infection of the wound, with all the dangers of suppuration of the bone and the torn and lacerated tissues, demands most careful consideration.

A large proportion of compound fractures are produced by direct violence, which is likely at the same time to produce serious bruising of the soft parts. A fracture produced by indirect violence and rendered compound by puncture of the soft parts by the end of one of the fragments, may under appropriate treatment heal almost as kindly and readily as a simple fracture. On the other hand, when direct violence is the cause and when the injury to the bone is accompanied by laceration and bruising or by destruction of the soft tissues, or by serious injury to important blood-vessels and nerves, the external wound can heal only by granulation. Indeed, in some cases the injury to the soft parts may be so great as either to render the limb useless, even if the wound should heal, or seriously to menace the patient's life.

Shock, as a rule, is greater in compound than in simple fractures, and it alone may cause death. In a large proportion of the cases of compound fracture due to railroad injuries, shock has proved, in my experience, to be a most prominent feature.

The conversion of a simple into a compound fracture may take place in a variety of ways. For example, the patient, ignorant of the nature of his in-

jury, may make the attempt to use the fractured limb and thus force a fragment of the bone through the overlying soft parts; or he may do the same while in delirium or in a state of alcoholic intoxication.

Sloughing of the damaged soft parts and possibly infection of the bone itself may add greatly to the gravity of the case. To ward off as much as possible such grave complications, and to mitigate their severity when they appear, should be the chief objects to be attained by the treatment. Cleansing of the wound and immobilization of the fractured limb by suitable dressings constitute, it is scarcely necessary to state, the first steps in any plan of treatment that may be adopted in these cases.

In some gunshot wounds and in injuries due to great violence—as, for example, the crushing of a limb by a heavy weight or by the wheel of a railroad car or a heavily loaded wagon—amputation may be imperatively demanded. In other cases it may be thought best to adopt the more conservative plan of performing a resection of the damaged part of the bone, the torn soft parts and all foreign substances being removed at the same time under strict aseptic precautions. The carrying out of this plan often results in the production of a limb which, while somewhat shortened and otherwise impaired, nevertheless possesses a considerable degree of usefulness. In a certain number of serious cases complete repair, with perfect restoration of function, may take place.

Gunshot fractures present a remarkable degree of variety; in some of them there is merely a slight fissure on either the proximal or the distal side of the bone, while in others there may be a punctured fracture or an extensive compound comminuted one. The character of the fracture depends to a great extent upon the size and velocity of the projectile. (For a full discussion of this subject the reader is referred to the article on Gunshot Wounds in the preceding volume.)

Frequency of Fractures and the Degree of Liability of Different Bones.

While all bones are liable to fracture, some show a far greater liability than others. Furthermore, this liability of certain bones varies with the age of the individual. Treves, in his "System of Surgery" (edition of 1895), briefly states that "fractures are among the commonest injuries." He further cites P. Bruns as showing that "from over 300,000 cases of injury taken to the London Hospital during 33 years, they [fractures] constitute one-seventh of all injuries, are somewhat more frequent than sprains and ten times more frequent than dislocations."

As to the different sites of fractures, we again quote as follows from Treves: "Gurlt, using nearly 52,000 cases from the same source, calculates that fractures of the forearm bones formed 18 per cent of the whole; of the leg bones, ribs, and

clavicle, each 15 to 16 per cent; of the hand bones, 11 per cent; humerus, 7.8 per cent; femur, 6; foot bones, 2.9; face bones, 2.4; skull, 1.4; patella, 1.3; scapula, 0.8; spinal column, 0.3; pelvis, 0.3; and sternum, 0.1 per cent." He also mentions fractures of the upper extremity as occurring twice as frequently as those of the lower—52.60 per cent of the former, and 25 per cent of the latter. The late Samuel D. Gross, M.D., in his monumental work on "Surgery" (fifth edition, 1872, vol. 1, page 906), gives the following tabular statement:

	Number of cases.	Upper extremity.	Lower extremity.
Pennsylvania Hospital	1,473	572	901
Hôtel Dieu, Paris	1,856	850	1,006
Middlesex Hospital, London	1,280	764	516
Naval Hospital, Calcutta	1,346	665	681
	5,955	2,851	3,104

Fractures occur about three or four times as frequently in males as in females; the greater number occurring in the most active decade of life, between 30 and 40. Epiphyseal fractures (diastases) are necessarily limited to early life. Of fractures of both bones of the forearm, of the radius alone, and of the clavicle, a far larger number occur between 10 and 20 than prior to 10. In explanation of this fact it may be stated that children in the earlier period receive greater care and protection and are less liable to violent movements; their bones are also less compact. Fracture of the neck of the femur belongs to advanced life and occurs more frequently in the female. The atrophy of the neck of the femur due to advanced age, the increased brittleness of bone at this period of life, and the change of direction to a right angle are the important factors in the production of these particular fractures. Treves (*op. cit.*) states that "Between the periods of growth and degeneration, when their strength is most needed, the bones are at their strongest. In spite of this, according to Bruns, 43.8 per cent of all fractures occur between 30 and 60, while 26.1 per cent occur between 1 and 30, and 29.8 per cent between 60 and 90."

The degree of force sufficient to produce a fracture is quite variable and is dependent on the age of the individual in whom the fracture occurs and on the pathological conditions that may be present. Prof. H. Helferich, in his "Atlas and Epitome of Fractures" (published in 1902), gives the following table, which shows widely different results obtained by actual tests:

Bone Tested	Weight Required to Produce a Fracture.
Female clavicle	126 kg. (230 lbs.)
Female humerus	600 " (1332 ")
Male radius	324 " (720 ")
Neck of femur in man	815 " (1810 ")
Tibia	450 to 650 (1000 to 1443 ")

He further states that "In rare instances fractures have occurred without

any accident, while the individual was engaged in ordinary work, such as climbing a ladder with a load on his back." Occasional instances have been observed where the femur has been fractured by pulling on the boot, and also—in the case of other bones—by simply turning over in bed. As a matter of course, in these particular cases some pathological condition of the bone must have existed.

In rare instances fractures have occurred in intra-uterine life. Such fractures are generally due to violence or to pressure on the abdomen of the mother, although Hamilton states that they may be due in some instances "to simple muscular contraction."

General Etiology.

The causes of fracture may be (1) predisposing, and (2) determining or immediate.

I. *Predisposing Causes.*—Predisposing causes are: (*a*) External; (*b*) Normal or Physiological; and (*c*) Pathological.

(*a*) The external predisposing causes are the occupation, mode of life and environment at the time of fracture; these accounting for the greater number of fractures in males at their period of greatest activity. Although fractures occur with a greater degree of frequency in cold than in warm weather, this fact is not to be attributed to a greater degree of brittleness of bone at the time. It is also true that at this season the muscular system is in a more tonic state, and that the joints are held more rigidly, thus favoring to some extent fracture. Nevertheless, the insecurity of movement due to snow and ice, and the more hurried and incautious movements, must be considered the principal causative factors. Fractures occur more often in summer than in winter in children, as they lead a more active life at this season.

(*b*) The normal or physiological factors are position, form or shape, strength, and elasticity. As regards the first of these factors, position, it may be said that the bones of the extremities are used instinctively to protect the rest of the body, and are therefore more liable to injury than the trunk bones, which in turn are more difficult to protect than the bones of the head, and at the same time are less sedulously protected. A long bone lying in the direction in which force travels and receiving it, is more liable to fracture than one not so placed. Thus, the radius and the tibia are more often fractured than the ulna or the fibula; and yet, a twist of the foot, changing the line of force, may fracture the fibula alone. The form or shape of the bone will also have its influence in this respect. A comparatively straight or a short bone has relatively greater strength than a curved or a long bone. The strength and elasticity, which vary greatly in different bones, are important physiological factors. The ribs and the clavicle are much curved and relatively elastic, while the humerus, femur, and the

long and straighter bones are less elastic. With the same form and size, the greater the weight of a bone the greater is its strength. Cancellous tissue is comparatively strong and elastic and of great importance in destroying shock; hence its presence in the ends of long bones and in the bones of the vertebræ.

(*c*) Among the pathological predisposing causes may be mentioned: Caries and necrosis; primary or metastatic tumors of bone; pressure by non-osseous growths; osteomyelitis; osteoporosis; fragilitas ossium; osteitis deformans; echinococcus disease; syphilis and the deleterious effects of mercury; tuberculosis; atrophy from disuse or from circulatory defects; fatty degeneration; rheumatism and gout; pregnancy; rachitis; osteomalacia; insanity; locomotor ataxia; general paresis and diseases involving the trophic nerve centres; and, in some cases, hereditary influences.

Spontaneous fractures—*i.e.*, fractures which occur as a result of an apparently inadequate amount of violence—may be due to any of the causes enumerated above. A fracture caused by only slight violence should at once raise the suspicion of a malignant growth.

As stated above, a spontaneous fracture may also result from other pathological conditions. Thus, for example, the bone may be markedly atrophied, or, without any diminution of volume, its constituents may be greatly changed. Then again, the constant pressure of an aneurism or other growth of soft tissue may so reduce the thickness of a bone as to permit of its fracture under the application of a limited amount of force. In atrophy from disuse, tabes, general paresis and insanity, and from other nervous influences, the compact layer of bone may become impaired and fragile. It must be remembered, therefore, that the fractures seen in the patients of insane hospitals are not necessarily due to violence on the part of careless or brutal attendants.

II. *Direct Causes.*—The direct, immediate, or determining causes are external violence and muscular action. External violence may be direct; that is, fracture may occur at the place where the force is applied, as when a limb is crushed by a heavy weight, or when the leg is struck and the bone gives way at the point of greatest strain; or it may be indirect, as when the fracture is produced at a point more or less remote from the place where the force is received, as happens in a fracture of the radius caused by a fall upon the hand, or in a fracture of the clavicle when violence is received on the shoulder. A fracture sometimes occurs in consequence of sudden and strong muscular contraction acting upon a bony prominence or a portion of a bone which projects as a lever beyond its fulcrum. Examples of this may be found in fractures of the olecranon process of the ulna and in fractures of the patella; the former being fractured by the contraction of the triceps, and the latter by the similar action of the quadriceps femoris. Some of the epiphyseal fractures are common examples of this mechanism. If it were not for the fixation of certain bones by muscular action, in many falls a fracture would fail to occur. Instances of

the truth of this statement are furnished by the muscular relaxation of intoxicated and insensible persons.

Displacements of the Fragments after a Fracture.

Malgaigne gives us five varieties of displacements: Transverse or lateral; angular; rotatory; impacted or crushing; and longitudinal; and to these may be added a sixth, viz., depressed. A fracture, however, may present a combination of two or more of these, and sometimes the peculiarities are such as to prevent a practical classification. Displacements may be produced by fracturing violence, by muscular contraction, and by the force of gravity. Transverse displacements are somewhat rare and usually attend transverse fractures; they may take place laterally in either direction, or backward, or forward. When a transverse fracture is complete, longitudinal displacement is apt to take place, and in oblique fractures lateral displacement usually accompanies the characteristic longitudinal deformity. Angular displacement is

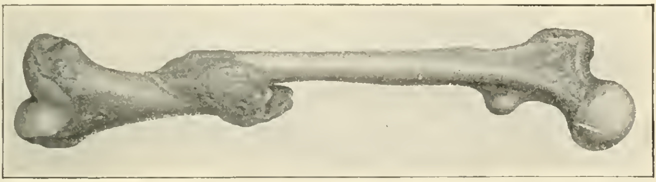


Fig. 14.—Fracture of the Lower Portion of the Femur, with Displacement and Axial Rotation of the Fractured Ends of the Bone. (Helferich.)

common, being characteristic of incomplete and deeply toothed fractures; it is also often encountered in simple transverse fractures. In oblique fractures angular displacement, combined with overlapping of the fragments, is of frequent occurrence. In rotatory displacement, one fragment, usually the lower, turns on its long axis, while the other remains in position. (Fig. 14.) In fracture of the radius, when the break occurs above the insertion of the pronator radii teres, rotation outward of the upper fragment is the result of unopposed contractions of the biceps and supinator brevis; and, as no muscle is attached to it which is capable of producing supination, we are obliged to employ forcible supination in order to make the lower fragment conform to the upper. *Overriding* is common in oblique fracture of the shaft, and is produced chiefly by contraction of muscles; it is favored by the swelling of the tissues due to inflammation and extravasation of blood, both of which increase the transverse diameter of the limb at the expense of the longitudinal. In *impaction*, the smaller fragment is impacted in the larger; the cancellous ends of long bones being usually the

seats of such impaction. So long as impaction exists, the conditions are most favorable to union. Some angular displacement, however, is apt to be present at the same time. *Direct longitudinal displacement* (separation) is the condition most often found in fracture of the patella, and is due to the contraction of the quadriceps femoris and also in some measure to distention by blood and fluids within the joint. *Depression* is practically limited to the flat bones of the skull, in which the bone fragments are displaced below the level of the normal surface of the bone. In the upper third of the femur, the line of fracture is usually from above downward and forward; the lower fragment, under the contraction of the hamstring muscles, glides upward and backward and pushes forward the upper fragment, while the psoas and iliacus muscles, in their turn, aid in producing the deformity. If the line of fracture runs inward or outward, the lower fragment, as it ascends under contraction of the muscles, is apt to push the upper fragment in the opposite direction; and if the line runs in the unusual direction of backward and downward, the weight of the lower fragment will hold down the upper, and thus aid in maintaining apposition of the fragments. While muscular contractions are a very important factor in the production of displacements, gravity is the only natural force that will tend to counteract the shortening produced by muscular contraction; but this power is often held in abeyance by the horizontal position. The terms *early displacement* and *late displacement* are used to distinguish between displacements found soon after the occurrence of the fracture and those which may subsequently happen as a result of unlocking of fragments or of yielding on the part of restraining muscles, or as the result of external violence or of manipulation.

Injury of the Soft Parts.

The periosteum may only be loosened from the surface of the bone, or it may be torn across entirely or partially at the seat of fracture; it may also be detached completely from some of the fragments. In proportion to the amount of injury inflicted upon the periosteum will probably be the rapidity and perfection of repair. Thus, in subperiosteal, partial, or "green-stick" fractures the prognosis will be far more favorable than where there is decided injury or destruction of this membrane. Complete rupture around the site of the fracture is comparatively rare and is limited usually to fractures in which there is great displacement of the fragments. The periosteum may be stripped off entirely over a greater or less extent, but if its continuity is preserved at one side, in such a manner as to form a "periosteal bridge," it will serve as a valuable factor in promoting repair.

The muscles, fasciæ, and other tissues may escape injury entirely, or they may be extensively lacerated or contused, or even separated completely by the original violence, by improper movements of the parts, and by the irregular,

sharp-pointed ends of bone. It is important to see that the soft tissues which may have been displaced are not interposed between the fragments, as such a condition will materially interfere with, if not prevent, union.

The skin may either be lacerated by external violence or punctured by a sharp fragment of bone; or it may subsequently slough if undue pressure by a displaced fragment or by an improperly applied dressing is permitted to remain unrelieved. Injuries to important blood-vessels and nerves will claim consideration under the head of "Complications," as will such visceral injuries as puncture or laceration of pleural or pulmonic structure in fracture of the ribs, etc., under "Special Fractures."

Signs and Symptoms.

The objective or positive signs, which are by far the most important, are abnormal mobility, deformity, and crepitus; while the subjective or rational symptoms include the history of the injury and of the patient, pain, and loss of function.

The existence of mobility in some part of the bony framework where it does not naturally exist—a mobility which is at once apparent or which becomes evident only when one portion of the limb is held firmly while the remaining portion is subjected to a certain amount of movement—may be regarded as pathognomonic. "The unbroken bone is nowhere mobile in continuity" (Da Costa). Mobility, however, may not always be recognizable, as in partial fractures or when one of the fragments is too small or too deeply seated to be grasped. In rachitis the bones will sometimes bend; and the normal elasticity of the lower ribs, metasternum, and possibly the fibula is apt to deceive one who is not a careful observer. This aspect of the subject will claim attention in the consideration of "Special Fractures."

The *degree of displacement* may be so marked that at a casual glance a fracture may be readily recognized by the character and extent of the deformity. In other instances it will be found necessary to employ careful inspection and palpation, to institute a comparison between the injured limb and its normal fellow, and to make accurate measurements. The deformity may be misleading by reason of pre-existing asymmetry or on account of the swelling due to the presence of inflammatory products and blood—the results of the injury inflicted upon the soft parts. In the matter of measurements a knowledge of the location of certain well-defined anatomical points is essential. In fractures of the femur, for example, and especially in those of the neck of the bone, the uppermost points which serve as guides are the trochanter, the tuberosity of the ischium, and the anterior superior spine of the ilium. In fractures at the lower end of the radius the important points are the styloid processes of the radius and ulna; and in those near the elbow the guiding points are the condyles of the

humerus and the olecranon, all of which points may be to some extent greatly obscured if the examination is delayed until the usual tumefaction has developed. When a comparison is instituted between corresponding limbs, either by inspection or by measurement, it is essential that their positions at the time should be identical. In fractures involving joints, there will be marked deformity due to filling of the joint cavity with blood or with inflammatory products. Such fluids, however, will be limited in extent by the attachments of the articular capsule.

Crepitus may be apparent to the ear of the surgeon, or it may be limited to a peculiar grating sensation which is communicated to the hand—a sensation that is produced by the friction of the ragged edges of the bony fragments. This sign, which is pathognomonic, varies greatly in degree in different cases, and cannot be produced unless there is a certain amount of mobility; it is dependent on the relation of the fragments, which must, as a matter of course, be in contact. If the fragments are separated to any great extent, or if a portion of muscle, fascia, or other soft tissue is interposed, or if it is not sought for until callus covers the edges of the fragments, it will not be discoverable; and, finally, the manipulations that will produce it at one time may fail at another. Error may arise from roughness of adjacent joint surfaces, from inflammation of tendon sheaths or bursæ, or from the crackling of coagulated blood. In these conditions, however, the sound heard or the sensation conveyed to the touch is softer, smoother, and less sharp, hard, or rough. Direct observation by the Roentgen or *x*-rays, with or without fluoroscopic or photographic aid, will in nearly every instance give decided and definite information of the greatest value and importance, and in any case in which there is the slightest doubt or uncertainty it should invariably be resorted to. It will also afford most valuable information as to correct apposition after adjustment and dressing of the fracture. It ought not to be necessary to seek for crepitus in making a diagnosis of fracture, since the determination of a false point of motion will quite invariably be attended by it. A vigorous effort to determine the presence of crepitus is too often fraught with harm to justify the act, except in remotely special instances.

Ecchymosis, though rarely absent, may not make its appearance for several days, and is most manifest in the aged, the lean and muscular, and the alcoholic and opium habitués. The blood, making its way along the planes of muscle or fascia, may first appear at a distance from the point of fracture, as beneath the malleoli in Pott's fracture, and above or below the wrist in Barton's or Colles' fractures. An extensive contusion over a superficial bone, presenting a soft compressible centre, surrounded by a ring of hard, condensed tissue and coagulated blood, may simulate a fracture. "Linear ecchymosis has been esteemed by some as a sign of fissure, and is often noted after fracture of the fibula. Linear ecchymosis over the line of the posterior auricular artery was shown by

Battle to be a valuable sign of fracture of the posterior fossa of the base of the cranium." (Da Costa.)

In order rightly to interpret the *subjective or rational symptoms* it is desirable to obtain a complete history of the patient's previous condition as to any of the pathological features mentioned as among the predisposing causes, together with full and minute information as to the exact nature and character of the injury. In some cases, however, it will be found that the patient is not able, on account of preoccupation or for other reasons, to give a clear, satisfactory, and reliable statement.

Pain may be lacking altogether or be only slight in degree in cases of partial fracture and also in cases in which the fracture occurs spontaneously, as in rickets and in other pathological conditions of bone. It may range from slight to extremely severe or torturing, and in the latter case is suggestive of changes due to the subsequent movement of the parts rather than of lesions produced at the time when the injury occurred. In indirect fracture the pain may predominate either at the site of the fracture or at the point where force was applied. In a direct injury the pain and tenderness from contusion of the periosteum or superjacent tissues cannot always be differentiated from the same symptoms when they owe their origin to the fracture itself. The pain of contusion, says Helferich (*op. cit.*), may be differentiated by establishing the fact that careful manipulation of the limb produces pain over a large extent of the injured region, while in fracture "it is intense and localized to a definite point." "Spontaneous pain when the part is at rest is usually slight, not distinctly limited to the injury, and not significant; but localized pain on pressure, on movement of the bone, and on pressing the fragments together is a valuable symptom, and sometimes the most positive one that can be obtained, and sufficient in itself for diagnosis. It is to be sought for by pressure with the tip of the finger along the line of the bone, by pressing one end of the bone toward the other, or, more rarely, by gentle lateral or rotatory movements communicated to the lower portion of the limb while the upper is fixed, or by making the patient contract a muscle attached to the bone while its movement is opposed, as in fracture of the calcaneum or olecranon. It is of great diagnostic importance in the absence of the positive signs, and is therefore specially valuable in many fractures near the end of a bone and in those of the metacarpals and metatarsals and ribs, and its absence is often a means of excluding fracture." (Stimson.)

The *disturbance of function* may vary considerably, and while there have been undoubted cases of impacted fracture of the neck of the femur or of fracture of the fibula alone, which have permitted the patient to walk considerable distances; cases also in which the arm has been used after fracture of the ulna; and cases in which the patient has remained standing at his work after a compression fracture of the vertebræ, yet the bending of the lever through which the muscles act, or the inhibitory effect of pain or the fear of it, usually

occasions a complete or partial loss of function. Indeed, in most cases of fracture of one of the long bones, the limb is either practically helpless or its functions are greatly impaired. The absence or retention of function is not necessarily indicative of the presence or absence of fracture.

Diagnosis.

In the diagnosis of fracture a knowledge of the landmarks, including especially the bony prominences near the joints, is of great importance; and so also is the assistance that may be derived from accurate measurements and from a careful comparison of the injured bone with the corresponding bone on the other side of the body. Careful palpation to determine the degree of deformity or displacement that may not be apparent to the eye, and such manipulations as will enable one to ascertain whether any preternatural mobility exists, are also measures of importance. Finally, aid may be obtained by the employment of percussion and auscultation combined. If the stethoscope is applied over the injured bone and if the latter is then percussed, the note will be distinctly heard so long as there is no solution of continuity between the stethoscope and the point of percussion; but, if a complete fracture intervenes, the waves of sound will not reach the ear applied to the stethoscope.

A supposed fracture should be examined as soon as practicable after receipt of the injury,—if possible, before the onset of swelling,—and the injured part, as well as the corresponding half of the body, should be thoroughly exposed to view. If the nature of the injury is doubtful, if the patient is very nervous, or if he suffers great pain, it may be well to administer ether as an anæsthetic. While he is under the influence of this drug it likely will be possible, not only to make a correct diagnosis, but also to adjust the bone fragments and to apply such measures as may be needed for retaining the fractured limb in position. Injuries of the elbow joint nearly always justify the employment of an anæsthetic, while Colles' fracture may in many instances be diagnosed by the experienced at a glance.

The preternatural mobility of the part, the possibility of readily reducing the deformity, which returns as soon as the reducing force is withdrawn, and the contrast between the crepitus on the one hand and the restricted mobility on the other, are of great service in differentiating a fracture from a dislocation, which, when reduced, remains in position. In a dislocation the entire bone moves as one piece, the bony prominences retain their normal relation to the remainder of the same bone, and the head of the bone is found out of its socket. We must remember, however, that a dislocation and a fracture may exist at the same time, and also that the rubbing of a dislocated bone against the edge of the articulation, if the joint surface happens to be roughened by inflammatory deposits, may simulate the crepitus of a fracture.

The diagnosis of impacted fracture may be difficult. Tumefaction may obscure the deformity, and, unless the fragments are separated, crepitus and abnormal mobility will be wanting. Fissures are also difficult of recognition, and may present no evidence other than localized pain and a linear ecchymosis after several days have elapsed.

In children the difficulty of making a diagnosis is enhanced. The bony prominences are not so sharply defined, crepitus is not so marked, and pain may be trivial. In a partial, subperiosteal, or "green-stick" fracture, the deformity and impaired function also may be slight, to be subsequently greatly increased unless the real condition be properly recognized and corrected. The nature, extent, and direction of the violence, the site and character of the pain on manipulation, and a careful study of the slightest deformity and other clinical features sometimes suffice to give a correct clue. If the surgeon be at all in doubt, it will be his best course to give the patient the benefit of the doubt and to treat the case as if a fracture really existed, at least until the true state of affairs can be ascertained with certainty.

Epiphyseal fractures are diagnosed by the patient's age, by the preternatural mobility and the deformity of the affected limb, by the presence of pain, and by the swollen and ecchymosed condition of the skin in the vicinity of the line of separation. An epiphyseal separation is sometimes incomplete, and when this is the case there will be soft crepitus and but little, if any, deformity.

Great tumefaction may mask the character of any injury and it may have to be subdued by cooling lotions, by pressure exerted through a carefully adjusted bandage, and by time; it being sometimes necessary to wait several days before it is possible to make a correct diagnosis. But, as previously mentioned in connection with semeiology, the Roentgen or *x*-rays will be found of great value in clearing up the diagnosis. Their application may require the services of an expert, but the reading of the radiographs or of the fluoroscopic views, which should not be limited to one side, usually prove an easy task to the surgeon. Other features of diagnosis will receive attention when we come to consider "Special Fractures."

In a *physical examination* of a supposed or existing fracture the greatest gentleness and care, consistent with obtaining as thorough a knowledge as possible of the exact nature of the injury, are requisite; and, while harshness and rude violence are at all times to be deprecated, yet a certain degree of firmness and positive manipulation should be employed whenever such a course seems to be necessary in order to gain a correct knowledge of the existing conditions. It seems best, therefore, in any case of a doubtful nature or where the part injured is located near a joint, to put the patient completely under the effects of a general anæsthetic; and yet one must not forget that, with the patient in a state of complete unconsciousness, the making of a physical examination entails increased responsibilities. Although some surgeons of wide

experience may in many instances arrive at a diagnosis and reduce the fracture without the aid of a general anæsthetic, I feel justified in recommending to those in general practice a more frequent resort to the use of an anæsthetic, both for the purpose of perfecting their knowledge of the injury and for that of facilitating the application of the best therapeutic methods. It may not be necessary to use it as an immediate measure, and its employment may be deferred until a permanent dressing is to be applied, but it should not be lost sight of in any case of slightest doubt or uncertainty.

In *x*-ray examinations certain points are always to be borne well in mind. Successful results require, in the first place, special study and training; and always two or more views—at least an antero-posterior view and a lateral view—should be taken if a clear idea of the displacement, or possibly even the knowledge of the existence of a fracture, is to be obtained. It is necessary here, as it is in making comparative measurements, to secure views of the corresponding limb made under precisely the same conditions. Furthermore, the possible exaggeration of the appearance of the deformity in the skiagraph must be borne in mind. A thorough knowledge of the normal shape of the bones (as seen in the skiagraph), and especially of their articular ends, is of the utmost importance; otherwise, the line of an epiphysis, an accidental indentation, or a dark line might be mistaken for a fissure or for a line of fracture. In *Progressive Medicine*, December, 1900, is a most excellent review by Wolff of the discussions which have been held on this subject; and in it he refers to the necessity of a correct knowledge of the times of ossification of the different epiphyses in order correctly to interpret *x*-ray representations of these fractures. The skiagraphs obtained prior to and after ossification are quite different. (Consult also the article on "The Epiphyses and Their Radiographic Interpretation," in Vol. I.)

Processes of Repair.

The process of the repair of bone is essentially the same whether it takes place in a simple or in a compound fracture. But when the bone is comminuted and the soft parts are extensively lacerated, and especially when these conditions are complicated by infection, the reparative process is subjected to certain modifications. The histological features of the process are not materially different from those of normal growth or exaggerated nutrition in other tissues of the body.

The effused blood, to which the first stage of tumefaction is due, is poured out around and between the ends of the broken bone. It comes from the ruptured vessels of the bone and its periosteum, and from those which lie in the interstices of the muscles. The resulting clot is gradually absorbed during the first few days following the injury. The blood-clot does not specially contrib-

ute to the repair of the bone; as it disintegrates it is carried off by the leucocytes. The cells of the torn tissues proliferate and occupy the space previously occupied by the clot. The products of this proliferation—the fibroblasts—soon become vascularized and are thus converted into granulation tissue. Osteoblasts, emanating from the deep layer of the periosteum and from the medullary tissue, proliferate rapidly soon after the injury and become widely distributed through the mass of fibroblasts. These osteoblasts may form bone directly, but in some instances they develop first into cartilage, which may subsequently be converted into bone. If the osteoblasts are not sufficiently active in their proliferation, bone is formed in scanty amount or not formed at all. If the mass of granulation tissue becomes fibrous tissue, a fibrous union will take place between the ends of the fractured bone; but, if the proliferative process is a little more active, cartilage alone may be formed, and a cartilaginous union will then result. (Vide "Repair of Fractures," page 279, Vol. I.)

During the process of repair the ends of the bone soften and some of the bone is carried away by osteoclasts, which, according to Senn, are large osteoblasts that supply a secretion that dissolves bone. The mass of tissue that surrounds the fragments—a tissue which at first is soft, glutinous, and almost white in appearance, but subsequently becomes firmer and at last quite hard—is termed *callus*. It is applied successively to the fibroblastic tissue, granulation tissue, fibrous tissue and bone, and has no well-defined outline. It involves not only the bone and periosteum, but also the adjacent connective tissue and some of the muscular tissue, the ends of the fractured bone being deeply embedded in the dense mass, which is more firm than the exudate pertaining to inflammation of other tissues.

The term *provisional* or *temporary callus* is given to this mass of newly formed tissue that envelops the ends of the bones. It is also termed an *ensheathing callus*, being derived from the deeper layer of the periosteum. The *central callus*, which develops in the canal of the bone, is derived from the medullary tissue. The amount of provisional callus depends on the condition of the patient, on the degree of separation of the fragments, and on the amount of motion that exists between them. After a time the ensheathing callus is removed by the action of the osteoclasts, and later the central callus may also be absorbed, with a restoration of the medullary cavity, although this does not always occur. An excessive amount of provisional callus may implicate adjacent tendons, may unite parallel bones, as the ribs, ulna and radius, and may even, in injuries in the vicinity of a joint, destroy the use of the articulation. Fragments which are entirely detached, but which are surrounded by provisional callus, may unite and cause no trouble. On the other hand, necrosis of the fragments and suppuration may occur. Temporary callus is usually removed in from eight months to a year after its formation.

Intermediate, *definitive*, or *permanent callus* is the material that forms di-

rectly between the ends of a broken bone, and its osteoblasts come from the bone itself. This callus is not removed by absorption; its porosity diminishes, and in time it becomes dense bone. The provisional callus is Nature's splint and is but temporary; the definitive callus is the substance lodged between the fragments and is permanent.

The time required for the repair of simple fractures and some compound fractures varies in different bones and at different ages, being less in the young than in the old, and more in long, cylindrical bones than in the spongy and more cancellous. The following statement in reference to this subject is important: "Phalanges are said to require 2 to 3 weeks; metacarpal, carpal, metatarsal, tarsal bones, and ribs, 3 to 4 weeks; clavicle, forearm bones, and fibula, 5 weeks; humerus and tibia, 6 to 7 weeks; both leg bones, 8 weeks; femur, 10 to 12 weeks. By these times the bones mentioned are generally, after simple uncomplicated fractures, united with sufficient firmness to allow of use being commenced." (Treves.)

In compound fractures with great destruction, laceration, and injury of the soft parts, with comminution of the bone, and with infection, the results will not be so favorable and satisfactory. The sloughing of lacerated and torn tissues is usually followed by infection and suppuration. The fragments that are completely detached and denuded of periosteum will, if not removed, become necrotic. If treatment fails to overcome the infection pus is likely to burrow between the tissues and form abscesses. The casting off of necrotic fragments of bone proceeds slowly and the formation and ossification of the new granulation tissue are necessarily delayed. Usually the callus formed is of large dimensions. The ends of the bone may become necrosed, preventing the formation of the intermediate callus, or they may unite by the aid of an excessive amount of ensheathing callus, which in turn may become permanently ossified. The necrosed bone may form a sequestrum which will be retained for a varying length of time—a state of affairs which means the continuance of suppuration for an indefinite period and, if not relieved, may even necessitate amputation of the affected limb.

Complications of Fractures.

Among the complications and sequelæ of fractures may be mentioned the following: Injury to vessels and nerves; injury to joints; dislocations and ankylosis of joints; infection, suppuration, and gangrene; fat embolism; pneumonia; delayed union, non-union, and vicious union; and the development of malignant and non-malignant tumors. Tetanus, erysipelas, etc., regarded by some as complications of fractures, have no direct relations thereto other than to any traumatisms of the skin and other tissues.

Injuries to Blood-vessels and Lymphatics.—The main artery of a limb or some

of the smaller arteries may be divided or their coats lacerated and contused in both simple and compound fractures. In all cases of fracture of the bone or bones of a limb the arterial circulation beyond the point of injury should be closely and carefully investigated; and if, from the knowledge thereby obtained, it should be determined that hemorrhage is resulting from an injured artery, the bleeding should at once be controlled. The best way of effecting this is to ligate the vessel above or at the point of injury. If the ligation is done at the point of injury, both a proximal and a distal ligature should be applied. However, a ligature applied at some point higher up, in conjunction with elevation of the limb and properly adjusted pressure, may suffice. Serious hemorrhage is usually indicated by the great amount of early swelling, and cases have been recorded in which death has resulted from the bleeding of arterial trunks of moderate size.

In compound fractures the arteries in the vicinity of the injury should be carefully sought, and if they are found to have been divided or torn, they should be ligated if possible, both on the proximal and on the distal side of the seat of the injury. A bruising of the coats of the artery may subsequently result in the formation of an aneurism, which should as early as possible receive appropriate treatment. Radical measures may, however, be deferred until after union of the fracture has taken place, provided no serious contingency arises. From the bruising of an arterial trunk the formation of an embolus may result, and this may at any time give rise to serious trouble.

In this connection it should not be forgotten that ligature of one or more of the main arteries of a fractured limb may lead to gangrene and amputation. In such cases it is well to consider at the outset the advisability of prompt amputation.

If the large veins be torn, they too should be promptly ligated and the limb elevated and carefully wrapped to obviate gangrene. The lymph vessels may be injured, and such injury is likely to increase the œdema at the site of fracture. There may also be extensive oozing from the capillaries and other small vessels, which oozing favors early tumefaction. A few days later the inflammatory products still further increase the swelling.

Injuries to Nerves.—Motor and sensory nerves may be torn across, lacerated, or pressed upon by misplaced fragments. Divided nerves should be sutured at once. If paralysis due to division or injury of a nerve is not detected until after the patient has begun to make use of the limb, the ends of the nerve should be exposed and properly united. Restoration of function has followed such a procedure, even when it was carried out as long as a year after the injury. The prognosis, however, will be more favorable the earlier the injury is repaired. Nerve trunks are sometimes enclosed in the callus (Fig. 15), and should be released by operation as soon as the fact is ascertained. (Vide the article on "Surgical Diseases and Wounds of Nerves" in Vol. II.)

The Question of Amputation.—In cases of injury to the main arterial, venous, and nerve trunks, with or without extensive destruction of other tissues of the limb, the question of amputation becomes an important one for consideration, as a means not only of saving life but also of relieving the individual of a useless and possibly a disabling member. However, in deciding this question, the greatest degree of conservatism must be practised, for it must be remembered that notwithstanding very extensive destruction and mangling of tissue, the reparative powers of nature, more active in the young than in the aged, will sometimes accomplish most remarkable results. (Fig. 16.)

Fig. 15.—Musculo-spiral Nerve Thickened where it ran through the Callus of a United Fracture of the Humerus. The nerve was freed by chiselling away the bone, and the paralysis cured. (Helferich.)

Fracture Complicated with Dislocation.—In a fracture complicated with dislocation, the earlier the efforts to reduce the luxation the more likely they are to be attended with satisfactory results; when the line of fracture extends into the articulation the fragment may be temporarily but firmly fixed for the purpose by splints and a bandage. While in some cases this may be impracticable—as, for example, when the fragment is small—there are others in which these simple measures will not suffice. In these cases the operator will find it necessary to put the patient completely under the influence of an anæsthetic and then to reduce the dislocated fragment by manipulation with the hands and fingers, prior or subsequent to the adjustment of the fragments one with the other. In large bones, notably the humerus at the shoulder, if these measures fail, an incision may be made over the fragment, and the latter be pulled into place by means of the hook suggested by McBurney; or a strong pair of volsellum or other forceps may be used. In some cases, when the patient is under the influence of shock, it may be found unnecessary to administer an anæsthetic. No permanent dressing should be applied until the reduction has been accomplished.

Fig. 16.—Specimen from a Case of Severe Compound Fracture of the Femur. Owing to septic inflammation of the wound necrosis of a complete ring of bone followed; and, since under these circumstances it appeared unlikely that union would take place, an amputation was performed. (Helferich.)

Among the more or less serious sequelæ that are observed in fracture complicated with dislocation may be mentioned the following: Stiffness of a joint from want of use or from synovitis with adhesion; inhibition of the action of tendons from adhesive thecitis; the excessive formation of callus; misplaced callus; and ankylosis due to the presence of inflammatory exudate within the joint. For the relief of these conditions cautiously executed passive and active

movements and massage should be commenced as soon as the other conditions will permit. The use of a high degree of dry heat (baking) is often beneficial.

Infection.—Infection as a complication in simple fractures is rare, but may arise as a result of auto-infection, the germs being brought from a distant suppurating focus—as, for example, a simple furuncle. It is more apt to occur in such cases after rough handling of the limb and as a result of the lack of proper care and attention; it is also sometimes observed in cases in which the effusion and swelling are excessive. Infection will often convert a simple into a secondary compound fracture, the clinical picture of which, as well as the treatment, will practically be the same as that of an infected primary compound fracture. As soon as it is discovered that pus is present, it should at once be evacuated, and antiseptic measures with drainage should be instituted. In compound fractures, primary or secondary, infection may be mild, giving rise to only a limited amount of suppuration which may be readily controlled. In some cases, however, the most active, rapid, and fatal forms of infection are seen. Such an infection is especially apt to develop when the tissues are much bruised and lacerated, and the patient is broken down by the alcoholic or drug habit, by pre-existing disease, or by old age. The skin around the wound shows a dusky-brownish tinge which rapidly spreads upward particularly on the posterior and lateral aspects of the limb; the torn tissues become gray and less moist; a thin, offensive discharge escapes from the wound, and the odor becomes very offensive. The limb swells greatly far above the seat of the fracture; the surface of the body becomes dry and harsh, with possibly an icteric hue; the countenance shows an anxious expression; the body temperature rises; the tongue is coated heavily and is dark, dry, and brownish; and delirium may set in. When the skin near the wound manifests, on palpation, the emphysematous crackling which is due to the presence of the gases of decomposition, it may be assumed that the infection is of a most serious nature. Under these circumstances amputation may become imperative as the only means of saving life, and it may not avail. In other cases the infection may be arrested by the adoption of the following measures: Free incisions into the œdematous tissues; thorough drainage and a liberal use of antiseptics; free use of hydrogen peroxide in cleansing the diseased tissues; and the administration of tonics, stimulants, and a rich, nutritious, but easily assimilated diet. In any event, it may be expected that union will take place slowly.

In compound fractures, especially when they are infected by street dirt, careful scrutiny should be practised to detect the first manifestation of a gas-producing organism, notably the Bacillus aërogenes capsulatus. For, if delay in treatment happens here, then prompt amputation affords the only means of rescue.

Ulcerations, Sloughing, and Gangrene.—These pathological changes may be due to the constriction caused by improperly applied dressings, and to the

undue pressure exerted by immobilizing apparatus or by projecting fragments of bone. When the dressings are applied the ends of the toes and fingers should be left exposed, so that the state of the circulation in the limb may be readily investigated at any time. Shock not only causes general depression, but may even lessen in some degree the vitality of the fractured limb. Thus, for example, the constriction exerted by a narrow band of adhesive plaster, employed in the dressing, in case of fracture complicated by shock, has been known to occasion serious gangrene. Persons suffering from atheromatous vessels, cardiac disease, and diabetes are thereby predisposed to the development of gangrene. While this gangrene may, in some cases, be due to infection, interference with the circulation, as above stated, the severing of a large arterial trunk, the destruction or thrombosis of a large vein, and excessive tumefaction are its more common etiological factors.

Localized gangrene shows itself as a dark discoloration and induration of the skin, surrounded by an inflammatory zone, and beneath the dark and hardened patch of integument will be found a thin, dark or pinkish exudate of offensive odor. The infection may be arrested by a thorough removal of the dead tissues, free drainage, and antiseptic irrigations, and amputation will often be required. General gangrene of a limb is usually of the moist variety, beginning with coolness and discoloration of the ends of the toes or fingers, the part involved first becoming of a reddish hue and soon changing to a dark purple or bluish-black color. Dark blebs may appear on the surface, the epidermis being lifted up by a thin, dark, serous exudate. If the threatening gangrene is due to the constriction exerted by the dressings or by constricting pressure from any cause, the removal of the pressure may arrest the process; or it may be advisable to employ dry warmth until gangrene appears, when a warm aseptic or antiseptic solution (100° to 105° F.), preferably in the form of a continuous bath, may be employed. But when the conditions are more serious it will be found necessary to resort to amputation, either before or after a line of demarcation is formed; and, in performing this operation, it is desirable to utilize healthy tissues for flap material.

Fat embolism is a pathological lesion peculiar to fractured bone. It is caused by the liberation of fat from the medullary substance, some of which fat enters the torn veins and is carried to other parts of the body. It is eliminated by the renal emunctories, and may be detected in the urine a few days after a fracture of any magnitude. Globules of fat may be found plugging the capillaries of the brain, lung, and other tissues. So long as they are not infectious, and do not occlude the blood from any considerable part of a vital organ, no harm will follow. But occasionally, about the third day, a cerebral or pulmonic vessel of considerable size becomes plugged by an aggregation of fat globules, and as a result death may follow in twenty-four hours or less. Fat embolism may be deferred until after suppuration is set up, the pressure in the

bone being then so great that the fat globules are forced into the circulation. If the lung tissue is much involved, the patient will manifest the following symptoms: Sudden and violent dyspnœa; a cyanosed countenance and projecting eyes; cough, with the sputum frothy and mixed or streaked with blood; perhaps even hæmoptysis; and if the patient lives for any length of time he will scarcely fail to have pneumonia. When the cerebral tissue is involved, there may be sudden delirium followed by coma, the pulse will be small, thready, and irregular, and the patient generally dies. The character of the symptoms is not constant. The treatment is entirely symptomatic. It comprises such measures as counter-irritation to the chest, the application of warmth to the body and especially to the extremities, and the administration of stimulants.

Pneumonia may occur from hypostatic congestion, especially in such fractures as render it necessary for the patient to maintain the recumbent position for a great length of time. It is also likely to develop in the aged and in those who have a feeble circulation in consequence of some pre-existing constitutional disease.

In another group of cases pneumonia may occur as early as the second or third day. The predisposing cause in these cases is the pneumococcus, which is more potent because of the traumatism and of the increased susceptibility of the patient arising therefrom. The disease begins frequently without chill, is apt to run a rapid, severe course, with high fever and delirium, and often ends fatally in three or four days.

A *new growth* may, in rare instances, make its appearance at the point where the bone is fractured. The time required for its full development varies from a few weeks to a period of several years. The tumors which are observed in these cases are usually sarcomata, although distinct carcinomatous growths have been seen. Treves (*op. cit.*) makes two suggestions as to their formation: "(1) A fracture induces the formation of a mass of embryonic tissue (callus) in the place of the relatively quiescent cells of the bone and periosteum"; and "(2) irritation is often given as a cause of tumor." Farther on, he says: "but the chief interest lies, again, in cases of tumor developing in close time-relation with a fracture." Nevertheless, he adds, "this does not prove anything." However, the fact of the development of a new growth at the site of a fracture is, to say the least, quite suggestive.

In the case of a benign tumor it will be sufficient to remove it at as early a date as possible; but if the growth be of a malignant nature, removal of the limb at the nearest joint above the fracture will, in my opinion, be justified; and if the operation be done early, it may prevent a recurrence in another part of the body.

Delayed Union.—Delayed union occurs in about one in eighty cases (Treves), and may be the result of a deficient formation of callus or of its failure to undergo proper ossification. While the cause is not always ascertainable, the fol-

lowing etiological factors are important: A want of proper adjustment of the fragments and their satisfactory immobilization; the interposition of muscle or other soft tissues between the fragments; defective innervation; deficient and defective blood supply of one or more of the fragments; the want of suitable connection with nutrient vessels; and the influence of such constitutional disorders as anæmia, syphilis (in its later stages), diabetes, Bright's disease, rachitis, scorbutus, and the effects of pregnancy. Delayed union is akin to non-union, and the latter may be associated with it. In delayed union voluntary motion is hindered and pain on passive motion is often present; in non-union there is voluntary motion, and pain is slight or altogether wanting.

The first point in the treatment of delayed union is to ascertain the cause, if possible, and then to remove it by appropriate means. In anæmic and debilitated conditions this is to be accomplished by the administration of ferruginous and other tonics, the hypophosphites, etc. In all cases of late syphilis and of the other pathological conditions, it is well to anticipate delayed union by the administration of appropriate constitutional remedies. After all has been done in this direction, outdoor exercise and massage should be urged. In cases involving the lower extremities the ambulatory treatment of fracture may suffice. Good results have been obtained by applying moderate constriction to the limb just above the seat of the fracture, by means of an elastic bandage beneath which a roller is carefully adjusted. Thus the consequent venous hyperæmia may be safely controlled and confined to a definite point. More active measures consist in rubbing the fragments forcibly against each other with or without the use of an anæsthetic; also in puncturing or drilling the fragments subcutaneously with a small trocar; in wiring or suturing the fragments with absorbable ligature material (the latter preferable); and, finally, in carrying an incision down to the seat of the fracture and freshening the ends of the fragments by scraping, paring, or curetting. Six months or more may be required to effect consolidation. Other special measures will be considered under "Special Fractures."

Non-union.—Cases in which little or no reparative action takes place are rather rare. It is preferable, I believe, that the cases of fibrous or cartilaginous union, in all of which there is a failure of proper ossification and consolidation, should be considered cases of non-union. In all these, the etiological factors are the same as in delayed union; malnutrition, however, is doubtless the most potent factor in preventing the union of the ends of the fractured bone.

In addition to the measures suggested for the relief of cases of delayed union, there are others which may sometimes be employed to advantage in cases of non-union. For example, the injection of a ten-per-cent chloride-of-zinc solution, or of tincture of iodine, may produce the necessary degree of local stimulation. In some instances, especially when one of the long bones is involved,

cutting down upon the seat of the fracture, under strict asepsis, and freshening or sawing off the ends of the bones, may be found necessary. The bones may be sawn at an oblique or a right angle; or one fragment may be given the shape of a wedge and the other that of the letter V; or the form of steps may be thought preferable. Some surgeons believe that the best plan is to wire or suture the fragments, and doubtless in some instances it may be necessary to adopt this plan of treatment. I prefer, however, when such a course can possibly be adopted, to secure and maintain the close apposition of the fragments by properly adjusted dressings and by the employment of suitable external apparatus. The lower fragment may be reduced in size and forced into the medullary cavity of the upper one, or the "bone ferrule" of Senn may be employed. Fragments of bone may also be transplanted from adjoining fragments or from some other source. These and various other measures suited to particular cases will receive attention in the section devoted to "Special Fractures." Compound fractures are, as a rule, more apt to be followed by delayed union and non-union than are simple fractures. (Consult also the article on "Pseudarthroses," in this volume.)

Vicious union may be the result of non-reduction primarily, or of secondary displacement. It is often a feature of intra-uterine fractures. In cases of vicious union there is complete bony union of the fragments, but with angular or other deformity. Vicious union is also due to exuberant callus at or near an articulation, or to the consolidation of parallel bones, the function of which is thus interfered with. Lack of anatomical perfection may not interfere with functional perfection; yet, in some cases, particularly in fractures of the clavicle and radius in females, anatomical perfection is a matter to which the surgeon should give vigilant attention. In some cases vicious union is due to want of proper treatment on the part of the surgeon, and heavy damages have been awarded for such negligence; yet, in other cases the surgeon is in no wise to be blamed. In most deformities of the leg bones, refracture by the hands of the surgeon or by the osteoclast, with proper adjustment and immobilization, is the preferable course to pursue; but in complicated deformities near the ankle, wrist, etc., and in exuberant callus, open incision and the use of the mallet and chisel will be required. Success, in these cases, depends on the adjustment and retention of the fragments and on the observance of strict asepsis.

General Principles of Treatment.

A person sustaining a simple fracture of the lower limb may have the same converted into a compound fracture by injudicous movements or by improper handling, this being less likely to occur in fractures of the upper extremity or elsewhere. If it is necessary to remove an individual with a fractured bone, certain precautions should in all cases be taken. If the nature of the injury

or other circumstances do not permit immediate adjustment of the fragments, or if this is accomplished before removal, the limb should be securely fixed and retained in the most comfortable position possible, precautions being taken to secure relaxation of muscles that have a tendency to displace the fragments. Sound common sense will indicate the material that may be utilized for an emergency purpose. A walking-cane, an umbrella, pieces of board, a bundle of twigs, etc., may answer sufficiently well; or, if the arm be the part fractured, it may be confined to the chest wall, which thus acts as a splint. In the case of a fracture of a lower extremity the injured limb may be firmly attached to its fellow with a handkerchief or some other form of improvised bandage, with suitable extemporized padding between. When the lower extremity is involved it will be necessary to carry the patient to his home or to some place where suitable treatment can be had. This can be done by sliding him upon a stretcher, a window shutter or light door, or a broad plank, on which he can be carried; or, if the distance be such as to require it, he may be placed in an ambulance, a spring or other vehicle, a reliable attendant being by his side to steady the limb.

The most important and fundamental principles of treating a fracture are: *the proper control of inflammation, the correct readjustment or replacement of the fragments, and their maintenance in position until sufficient consolidation has taken place.*

As a rule, the earlier the adjustment of the fragments is attempted, the more readily will it be accomplished, and the greater will be the probability that satisfactory results will be obtained. While it is better if the reduction can be accomplished before the patient is moved, it is not always possible to do this; at the same time, reduction is always more readily accomplished during shock, the muscles being in a state of relaxation and the patient less sensitive to pain. On placing the patient on the stretcher and getting him into a wheeled vehicle, the surgeon should take charge of the injured limb, so as to prevent, as much as possible, any displacement of the fragments.

Prior to or just after "setting" a fracture, the limb should be thoroughly cleansed with soap and water, and if necessary shaved; a sponging with alcohol, whiskey, or camphor may succeed this. When a fixed dressing is applied, care must be taken to avoid pressure over joints or bony prominences, by placing close to them suitable compresses or pads; and it is particularly desirable to guard against unnecessarily tight or improper bandaging, the circulation in the fingers and toes serving as an index of the circulation of the limb. Splints should be light and yet unyielding, although sometimes elasticity is needed; and they should be thoroughly padded, especially over joints and bony prominences, and, if possible, they should be so arranged as to fix the joints above and below the site of fracture. The application of a primary roller bandage before the splints are placed in position is unnecessary and objectionable,

and may even be harmful. Pressure by the splint should be evenly distributed over the limb, and when properly applied it should secure to the patient a sensation of comfort and support of the parts. A retention apparatus should be sufficiently tight and unyielding to prevent displacement of the fragments and return of deformity, but should not be productive of pain or harm. It must be remembered, however, that the mere fact of restraining the limb from its accustomed movements, by keeping it in a position of absolute rest, may for the first few days be accompanied by some discomfort or even pain; but this discomfort is different in character from that produced by an improperly applied immovable apparatus, and a prompt investigation and

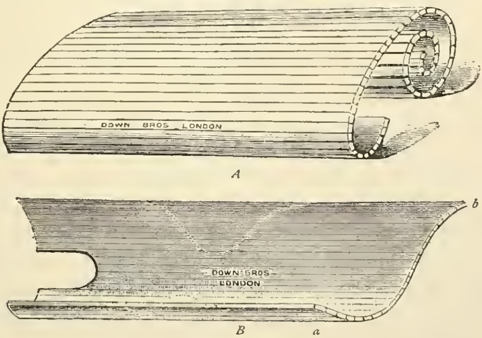


Fig. 17.—Gooch's Splinting. (From Cheyne and Burghard.) *A*, The roll of splinting before it is cut. The scored surface is uppermost in the figure, the one covered with American cloth being undermost; *B*, the splint cut ready for application to the lower limb. An aperture, *c*, has been cut for the heel, while the upper end of the splint, *ab*, has been cut obliquely from the inner side, *a*, upward and outward to *b*. The dotted lines indicated upon the splint show the manner in which it is sometimes still further cut away when it is desired to leave the knee exposed.

careful study of the patient and his peculiarities by the surgeon will generally enable him to discriminate between the two kinds of discomfort.

As already stated, the relaxation of muscles, the diminished susceptibility to pain, etc., that are associated with shock may enable the surgeon not only to make the diagnosis, but also to adjust the fragments; but, if it be found necessary, as it will be in certain conditions, to administer a general anæsthetic, suitable dressings should be ready at hand, to be applied before the patient recovers from the anæsthesia. The following quotation I most heartily endorse: "If the patient is very nervous, if the pain is severe, or if rigid muscles antagonize the efforts of the surgeon, reduce the fracture under anæsthesia. In some fractures (as in those of the clavicle) adjustment is effected by altering the position; and in others (as in those of the femur) by extension and counter-extension." (Da Costa.)

If the case is not seen until extensive swelling has taken place, it may not

then be possible either to make a correct diagnosis or to adjust the fractured ends of the bone. The proper course will be to wait until, by elevation of the limb, by the use of cooling and evaporating lotions, by the graduated pressure exerted by a carefully adjusted bandage, etc., these obstacles shall have been overcome. And yet it is needful to bear in mind the importance of early replacement of the injured bone.

The common dressings for retaining a broken bone in place consist of bandages (the ordinary roller, many-tailed, Scultetus', triangular, etc.), adhesive plaster, pads of absorbent cotton or wool, straight, angular, carved or turned pieces of wood (Fig. 17), leather, gutta-percha, cardboard and binder's board, copper, lead, tin, zinc, iron, or wire, and what are known as "immovable dressings," such as those made of plaster of Paris (Fig. 18), silicate of soda or potash, glue, starch etc., and specially designed apparatus for certain special fractures. The material to be used for splints is largely left to the choice of the surgeon. The qualifications needed for a retention apparatus should be strength, lightness, and, in some instances, elasticity. No material, it is safe to say, possesses all the required qualities. Wood comes near to fulfilling these requirements, yet it lacks elasticity, and is consequently not adapted for use in some fractures. I believe that a surgeon would be prepared to treat any ordinary fracture if he had at hand the following materials: Two boards, one one-fourth and the other one-eighth of an inch in thickness, about one foot wide and six or more feet in length; a few pounds of dental plaster of the best quality; a roll of wide zinc-oxide adhesive plaster; a few roller bandages; and crinoline or cheese-cloth and proper padding. By the aid of a saw or a knife the boards can be shaped to the size and form required; and, with the crinoline or cheese-cloth, plaster bandages can be readily prepared. With these materials properly fashioned a fractured finger, humerus, or femur can be conveniently and efficiently retained in proper position; for the retention of a fractured rib in position adhesive plaster will be needed. Carved or turned splints cannot always be recommended, for they are too often made to meet the desires of the instrument maker rather than the essential needs

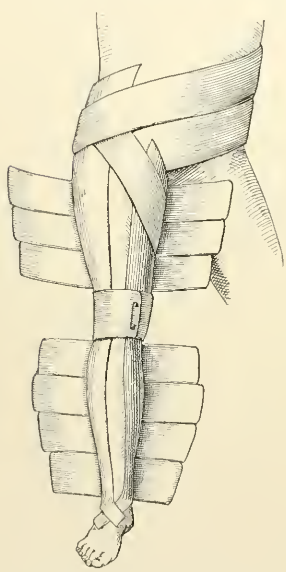


FIG. 18.—Strips of coarse Cloth which have been dipped into a Plaster-of-Paris Mixture and then placed behind the Limb in a position from which they can readily be folded over the thigh and leg after the manner of a bandage. (Pirogoff's method, from Esmarch's "Surgical Technic.")

of the surgeon or patient; and it is often the case that the fracture is compelled to fit the appliance instead of the appliance being made to suit the fracture. Finally, these manufactured appliances are often inaccessible when they are needed, and the same remark holds good as to complicated dressings, as well as to the specially designed "fracture bed." The ingenuity of the surgeon should be equal to the task of providing something which is more simple than the latter and which will accommodate the patient sufficiently when he has need to evacuate the bladder or the rectum. Thus, for example, a piece of stout canvas stretched upon a frame and so arranged that it may be hoisted by some simple device, will, as my experience teaches, answer the purpose as satisfactorily as a "Crosby bed." I do not desire to condemn such conveniences as are used in hospitals, infirmaries, and occasionally in private practice, but I regard them as conveniences or as luxuries that in many cases are not procurable, and I therefore advocate more simple means. Farther on, when I come to speak of the treatment of special fractures, I shall have occasion to refer to various kinds of special apparatus, and to express an opinion as to their practical value.

Operative Treatment of Simple Fractures.—In the *British Medical Journal* of November 18th, 1905, W. Arbuthnot Lane states that:

"It is now more than thirteen years since I devised the operative procedures in the treatment of simple fractures of the long bones, which I have systematically employed with uninterrupted success. I believe that this is the most efficient method at our disposal. The details of the operation are as follows: The skin is first made thoroughly clean. This sometimes takes several days. Moist compresses with careful scrapings are most effective in getting rid of suspicious material. After this a germicide is applied to make the skin as clean as possible. An incision is made which is large enough to enable the surgeon to deal effectually with the fragments. This incision should be made in a place which will involve a minimum chance of damage to important structures, and which will offer accessibility to the wound. The skin should be excluded from the wound by attaching sterile cloths to the cutaneous margins by forceps. After the fragments are exposed they are examined, and when all clots and material intervening between them are removed, they are brought into accurate apposition. Much traction may be necessary, as well as the leverage action of elevators and the approximating influence of powerful long-handled forceps. Strong compression forceps are used if there be any bleeding. When the fragments are accurately apposed, screws, silver wire, or staples retain them in position. The screw is generally the most efficient; but great care must be taken in drilling the hole to make it the right size for the barrel of the screw, otherwise the bone may be hopelessly comminuted. If much oozing is expected, a drainage tube may for a day or two be employed with advantage. Generally, a splint is required after the operation, but in certain cases it is impossible to employ any support."

The writer then cites the history of several interesting cases, and presents cuts of the lesions and of the special instruments used.

I cannot endorse this procedure as one that should be generally adopted; it seems to me that it is suited only to certain exceptional cases.

Modifications Needed in the Treatment when there Is Much Displacement of the Fragments.—With persistent overriding of fragments it may be found necessary to employ extension by a weight attached to the extremity, by the use of some elastic material, or by utilizing the weight of the limb to overcome the deformity. In some instances the fragments cannot be retained in position, and the surgeon is then justified in exposing the seat of the fracture by an in-

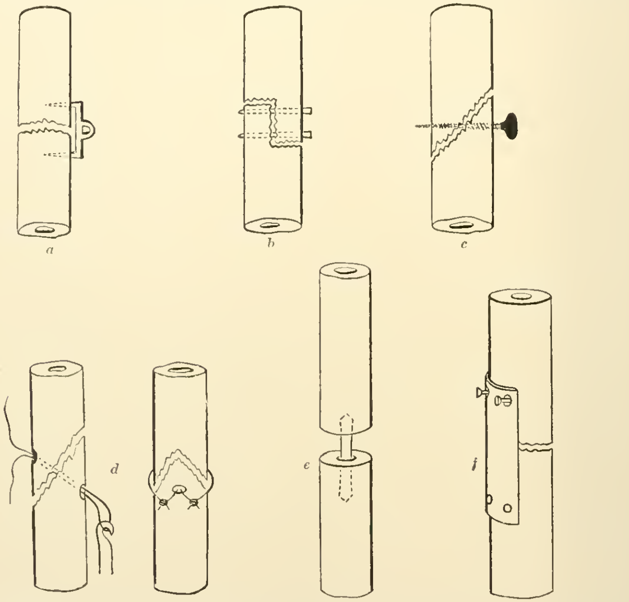


Fig. 19.—Different Methods of Uniting the Fractured Ends of a Long Bone. *a*, Gussenbauer's clamp; *b*, Schreiber's method of uniting the fractured ends of the bone by means of ivory pins; *c*, union of the fractured ends of the bone by means of a screw; *d*, Hennequin and Wille's method of suturing bone; *e*, employment of an ivory pin for securing union; *f*, method of keeping the fractured ends of a bone in firm contact by the aid of a suitable plate through which screws or nails are driven into the bone.

cision which will afford an escape to the accumulated blood or effused serum that may be present, and at the same time will permit of the removal of any soft tissues that may be present between the fractured ends of the bone. Furthermore, in the case of a comminuted fracture an incision will enable one to remove loose fragments of bone which have become entirely separated from their periosteal covering. If a large fragment is to be removed from the leg or forearm, the parallel bone may prevent the ends from coming together. In such a case

the resection of a sufficient portion of the unbroken bone may be required. In other cases it may be expedient to wire the fragments or attach them one to the other with screws, silkworm gut, absorbable sutures, or other devices. A suitable method of osteoplasty may be of utility in such instances. (Figs. 19 and 20.)

In a most practical article on "The Operative Treatment of Fractures," in the *Journal of the American Medical Association* of January 13th and 20th, 1906, Dr. James A. Kelly, of Philadelphia, goes very fully into the subject in its relation to all varieties of fractures, including recent open and closed, as well as ununited and other fractures. As to the "closed fractures" most suitable for this method of treatment he says:

"While it is not advisable or necessary to operate on all closed fractures, yet there are certain bones which, when fractured, generally demand operative interference if we would obtain the best anatomic and functional results. Many authori-

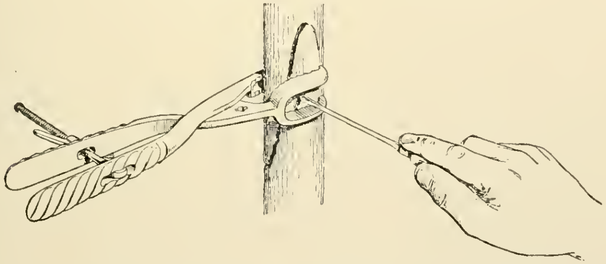


Fig. 20.—Peters' Forceps. (From Cheyne and Burghard.) As shown in the diagram, the fragments can be held firmly in apposition by this instrument while the bone is being drilled. These forceps are provided with an extra blade which can be made to replace the one shown at the right in the figure. The one here represented is the larger, and is employed when screws are to be used; the smaller one is designed for use when wires are to be inserted.

ties still maintain that no closed fracture should be converted into an open one, but there are some fractures in which even the most conservative surgeons will admit that, were it not for the danger of sepsis intervening, better functional results could be obtained by operation. Among such may be mentioned the following: (1) Fractures of the neck of the femur in patients under 50 years; (2) fractures of the femur; (3) fractures of the patella; (4) oblique fractures of the tibia either alone or in combination with fractures of the fibula; (5) fractures of the clavicle with marked displacement; (6) fractures of the upper end and of the condyles of the humerus; (7) fractures of the olecranon, with marked separation of the fragments; (8) fractures of the middle of the radius; (9) fractures of the spine and skull. In all cases in which marked comminution of the fragments is present and when reduction is impossible, in oblique and spiral fractures of the bones of the extremities, operative intervention is justified. Many of the deformities, pseudarthrosis, and loss of function seen to follow fractures will thus, in most cases, be obviated. The unsightly deformities which so seriously destroy the usefulness of the part and

predispose to refracture will be prevented. Fractures complicated by severe injury to adjacent structures urgently demand operation. Under this heading may be included fractures in which pressure is brought to bear on neighboring viscera, nerves, and blood-vessels, fractures associated with dislocations, and fractures involving joints.

"Not only does non-union often result from misplaced fragments, but excessive callus formation is bound to occur. Nerves and blood-vessels are liable to be involved in this excessive attempt of nature to repair the loss of bony continuity, and involvement of such structures is seen in the frequent neuritis and œdema of the parts following mal-union. When this excessive callus is formed at the seat of fractures involving joints, impairment and at times total loss of function are the result. Excessive callus is formed only when perfect approximation of the fragments is not obtained."

Direct Fixation of Fractures.—At the fifty-fifth annual session of the Medical Society of the State of Pennsylvania, September 26th–29th, 1905, as reported in the New York *Medical Record* of November 4th, 1905, the views of different surgeons were given in regard to the subject of fixation of fractures.

Dr. John B. Roberts, of Philadelphia, after discussing in detail the various methods employed in the fixation of fractures, including wire, catgut, bone ferrules, metallic plates, etc., said that, for transcutaneous fixation, he had at first used ordidary wire nails, but that afterward he had devised a surgical nail with a sharp point. He believed, however, that for the open fractures, or for closed fractures which had been explored, better results would follow the use of staples or plates.

Dr. George W. Guthrie, of Wilkesbarre, stated that his experience with direct fixation had been chiefly in cases of delayed union, and he preferred an end-to-end fixation and the insertion of a silver wire, which could be allowed to remain.

Dr. DeForest Willard, of Philadelphia, believed that direct fixation should be employed in all cases where it was necessary to bring the fragments of the bone into direct apposition, and he believed that the method should be decided by the individual case.

In an earlier issue of the New York *Medical Record* (May 5th, 1905) Dr. Charles A. Elsberg is reported to have made the following statements in regard to a new operative method of treating fractures:

"An ideal splint must be strong, of a material which can be moulded into any shape desired, must be easily sterilizable, should be easy of introduction, should tightly fit in the medullary cavity and fill it entirely, should have the form of a cylinder so as to allow the callus to grow through its lumen, and should have perforations so as to allow the circulation of fluids from the outside to the inside of the cylinder; and it should be of a material which is well borne by the tissues and should, if possible, stimulate the formation of new bone; also, it should be absorbed after it had served its purpose. He believed that all these requirements would be fulfilled by the absorbable aluminum cylinders, samples of which were presented. They were made of pure aluminum, could be easily sterilized by boiling in one-per-cent lysol solution, and would—so far as he could judge from his experiments on animals—be absorbed in the human body in about one year, on the average. The form that the aluminum

took in going into solution was, in all probability, aluminum hydrate, a salt that had antiseptic powers, and, from his experience, he believed that when the plates became infected the metal was able to sterilize itself. In the four cases in which he had thus far used the aluminum cylinders, the results had been very satisfactory. Two of these were cases of fracture of the femur, one of fracture of the humerus from a gunshot wound, and the fourth was a case of compound fracture of the phalanx. In short, his experience with the aluminum cylinders, although small, had impressed him with the favorable results obtained—the firmness of the union, the perfect immobilization, the aseptic healing, and the absence of shortening."

It is essential to say in this connection that all unusual methods of practice should be entertained with forethought and utilized with discretion, and by those whose experience and opportunity will justify their performance.

Modifications Required in the Treatment When the Fracture Extends into or close to a Joint.—If a joint is involved in the fracture, there will be an effusion of blood

Fig. 21.—Compound Fracture of the Humerus. (Massachusetts General Hospital.)

and serum within the joint, and possibly a plastic exudate may form upon the synovial surface, especially if the latter is involved in the line of fracture. The possibility that, in a more or less flexed position of certain joints, the opposite synovial surfaces will become adherent to each other if the joint is long kept immobilized, and that increased ankylosis will result, is apparent. And yet, moving the joint too soon or forcibly after the injury is liable to increase the amount of exudate and thereby the difficulty of overcoming ankylosis. The treatment advised here is the following: Rigid immobility of the part for the first ten days or, when essential, for even a longer period; lessening the amount of effusion by the application of the ice-bag during the first few days or weeks and then by the evenly applied pressure of a flannel or elastic bandage (if the latter is used, the pressure must be quite moderate); stimulating the circulation of the parts in the neighborhood of the fracture by passive motion and massage. In the passive movements the greatest care is to be taken to avoid disarrangement of the fragments. Primarily, the fractured limb must be so

adjusted that, after union has taken place, it will possess the greatest degree of utility even if ankylosis should result. It is possible, however, in many cases of fracture, by the aid of a general anæsthetic, to apply a force sufficient to overcome rigidity, even after complete consolidation has taken place. This is a matter that requires the greatest care and discrimination, and the massage and passive movements, when first resorted to in implication of a joint, must be of the gentlest character, and should be increased in force and extent gradually from day to day.

I approve of the plan of action suggested by Gillette in the following words:

"We rarely see a stiff joint after fracture if the bony structures are placed and maintained in their normal relations. While after-treatment with massage certainly does improve the circulation, there is great danger that in removing the dressings to perform massage the fragments may be displaced. Massage movement before union is also dangerous, not only because it may cause displacement, but also because of its likelihood to produce excessive callus. The essential things are correct reduction and maintenance in the correct position until union has taken place, which usually does not occur under six weeks. Then active instead of passive movement should be allowed, the limb being simply bandaged to prevent swelling. If reduction cannot be made without an anæsthetic, this should be employed; and if even then the fragments cannot be brought into place, the joint should be opened and the fragments fixed by wiring, nailing, or suturing. With clean surgury there is no danger in opening a joint. If there is a great deal of swelling or extravasation when the patient is first seen, then hot or cold applications may be used for two or three days before the limb is set."—(Gillette, *St. Paul Medical Journal*, Sept., 1906.)

Treatment of Compound Fractures.—Compound fractures require the same treatment, aside from the measures already mentioned, as do incised, contused, and lacerated wounds of the soft parts. If it be possible to do so, apply a wet antiseptic dressing to the wound, covering it with aseptic cotton or gauze before first moving the patient. All exploratory and other efforts then and subsequently *must, if possible, be conducted under strict asepsis,* it being remembered that there is no more active carrier of infection than the unclean hands and fingers of the surgeon. When a place suitable for the further treatment is reached, the patient should be placed on a table and his clothing be carefully removed. To avoid as much as possible moving the injured limb it may be preferable to cut off the boot or the shoe, etc., instead of pulling it off as is sometimes done, especially by thoughtless assistants. By keeping sterile gauze pressed lightly against the wound the limb may be thoroughly cleansed with soap and water, and shaved. The area immediately adjacent to the wound should also be shaven, cleansed away from it with ether, and douched with a 1:1,000 bichloride solution.

A thorough investigation of the extent and nature of the injury will, in many cases, necessitate the administration of a general anæsthetic, and, whenever it

is practicable, use should be made of the *x*-ray (Fig. 21). Bleeding vessels must be sought for and controlled, nerves united, and muscles and other torn tissues that are too extensively contused should either be removed or, if repair is considered possible, replaced in proper position and sutured. All foreign substances and detached fragments of bone that do not possess possibilities of reuniting with the sound bone should be removed; and drainage should be applied if it be deemed essential. It may be necessary, in order to secure free drainage and to replace fragments of bone in their natural position, to make additional incisions, preferably along the longitudinal axis of the limb. Sharp ends of bone denuded of periosteum should be removed. All the steps required in the treatment of wounds unattended with fracture having been taken, the integument may be closed over the wound as efficaciously as possible and a suitable fixation appliance adjusted. At the same time the importance of leaving the wound accessible to future dressings, without the necessity of disturbing the immobilizing appliance, must not be overlooked. If a plaster-of-Paris dressing is to be used, the wound should first be covered with a dry dressing, and over this should be laid a piece of oiled silk or rubber tissue large enough to extend some distance beyond it; the whole being confined in place by a gauze bandage. Then, after the limb has been properly covered with gauze or cotton-batting, over the whole a plaster-of-Paris bandage should be applied. Before the plaster completely hardens, however, a fenestra (Fig. 22) should be cut out at a spot corresponding to the site of the fracture, but the cutting must extend only down to the oiled silk or rubber tissue and not through it. After the fenestra has been made, slits should be cut in the oiled silk or rubber tissue in such a manner that it can be reflected back over the edges of the fenestra and fastened, in order to prevent infection of the plaster borders at this point by the discharges from the wound. Drainage should be provided in accordance with the accepted principles of wound treatment.

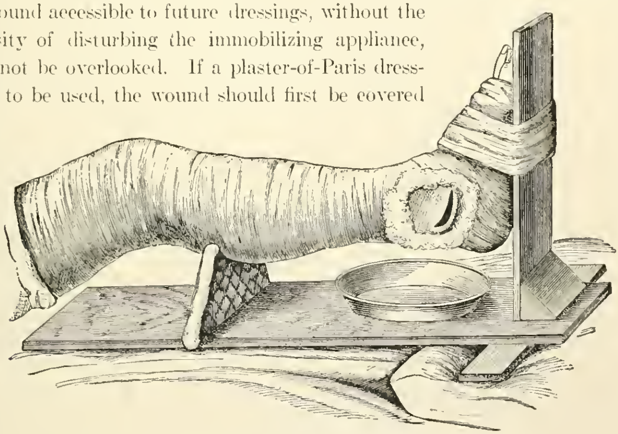


FIG. 22.—Fenestrated Plaster-of-Paris Dressing. (Esmarch.)

Ordinarily, in compound fractures the external wound should be at once protected by the application of an antiseptic pad, while thorough cleansing of the limb is practised by the means above stated. The wound itself and the contiguous area should then be cleansed, special care being taken to wipe *away* from the lesion. If bleeding have ceased or only oozing be present, and if the circulation be intact beyond, the parts should be disturbed as little as possible and placed in confinement under aseptic technique. Drainage should not be employed unless subsequently indicated by the appearance of the wound or by general manifestations. The great majority of cases thus treated will recover promptly without further special attention. In estimating the need of early drainage, the degree of injury of the soft parts and the evidences of the presence of infection are very important. Later, the onset of severe inflammation or of beginning suppuration, as indicated by the appearances of the wound, the temperature, and the blood examination, are of significant importance in respect to the need of prompt drainage. Compound fractures due to the crushing violence of the wheels of railroad cars and heavily laden vehicles usually come promptly to amputation, because of the great and extended violence done the soft parts and the comminuted state of the bones.

The Question of Amputation in Compound Fractures.—This question is one that requires very careful consideration on the part of the surgeon. Briefly stated, the following conditions may be considered as justifying amputation; although it must be remembered that, under the present modes of aseptic and antiseptic wound treatment, conservative measures may, even in cases of the gravest import, be attended with gratifying results. If, owing to local or constitutional conditions, extensive suppuration persists, notwithstanding the fact that everything possible—free incisions, perfect drainage, and irrigation—has been done to arrest it, amputation may be required in order to save the patient's life. If there has been extensive destruction of the soft parts, with or without injury to the large blood-vessels and important nerves; or if the bone has been injured to such an extent that when union of the available fractured ends takes place there will be a shortening so marked as to render the limb useless; or, finally, if gangrene should develop as a result of the injury to the vascular supply, amputation is generally accepted by surgeons as the best treatment. The location of the injury, the age, sex, and occupation of the patient, and the degree to which an artificial limb may act as a useful substitute for that which has been damaged, are all matters which call for careful consideration in these cases. The final decision with regard to the use of an artificial limb should be left to the patient. It must be borne in mind that, while it is important to save a limb or even a part of it, life is more important still, and that primary amputation will in many instances be preferable to secondary. Nevertheless, it is best not to reach a conclusion too hastily.

II. SPECIAL FRACTURES.

Nasal Bones.

Fracture of one or both nasal bones by direct force, such as a fall or a blow, is by no means uncommon. The free border of each bone is thin and unsupported, and is the part most frequently involved. When this portion is fractured, the cartilages attached to it may be separated or fractured. The fracture may be complicated or may extend to the superior maxilla, the lachrymal, or the frontal bones, and even the ethmoid may be injured. Displacement may be slight, as the fracturing force may only cause a flattening or deflecting of the nose. The injury may be compound externally and is usually compound internally, and when the latter event occurs there may be emphysema of the root of the nose, the eyelids, and the cheek, due to the forcing of air into the tissues in the efforts to clear the nostrils. If the nasal duct be involved this symptom is quite pronounced.

Diagnosis.—One or more of the cardinal symptoms of fracture, such as pain, swelling, false point of motion, crepitus, deformity, and epistaxis, are always present. It may be necessary to employ only gentle and careful manipulation in order to determine the existence of a false point of motion, or these symptoms may be wanting altogether; there may also be no discoverable displacement or deformity; or, if there be deformity, it may be masked by the swelling of the soft parts. However, a diagnosis can usually be made by means of palpation and inspection, but there are cases in which it is difficult or even impossible to make a diagnosis by these means. The introduction, beneath the nasal bone, through the nostril, of the end of a stiff probe or director, covered with gauze, is useful as a diagnostic and adjusting force when combined with external manipulation. Inflammatory products and blood-clot may block the nostril. Injury to the base of the brain may be a serious complication. Hemorrhage from the nose is apt to be profuse, but is readily controlled, and is not accompanied nor followed by oozing of cerebral or spinal fluid, as may be the case in injury of the base of the skull. In exceptional cases, when the cribriform plate of the ethmoid has been injured, the hemorrhage is persistent and cerebro-spinal fluid is present. Other complications are infection, abscess, and necrosis. The emphysema which is observed in some cases soon disappears. Obstruction of the lachrymal duct is to be expected when the nasal process of the superior maxilla is involved.

Treatment.—In external compound fracture the injury to the soft parts requires to be dressed in accordance with the general principles of wound treatment, it being found sufficient in most cases to replace the fragments and make provision for their retention in position during the first eight or ten days. A

small roll of adhesive plaster applied at each side of the nose and held in place with some pressure by a strip of plaster passed across the rolls from one side to the other may afford all the support that is needed. This plan of action serves to hold the integument in place and suffices, as a rule, to maintain the adjustment of the fragments. The application of collodion makes a good dressing in simple fractures, provided it be applied in several layers. If any difficulty is experienced in reducing the fragments by manipulation from without, the reduction may be accomplished by the introduction of a slender but fairly stiff probe, a director, or—what I have found very useful—a single blade of a long but strong pair of dressing forceps, rather thin at the ends. Roe's elevator is an excellent instrument for replacing fragments. The female catheter, the use of which is suggested in most text-books, is too thick to enter high up, especially if the space is encroached on by the displaced fragments. If proper care is taken in manipulating it, it will not be necessary to wrap or pad the instrument, whichever pattern may be selected. However, it may be found necessary to employ either general or local anæsthesia. Efforts to support the fragments by substances introduced into the nostril have not proved very satisfactory. If flattening recurs after the parts have been adjusted, a Mason's pin (Fig. 23) may be employed; or an ordinary steel pin with glass head may be introduced beneath the fragments, through the line of fracture; and then, over the projecting ends of the pin, figure-of-8 turns of silk or cotton yarn may be passed, for the purpose of retaining it in position. At the end of about ten days the pin may be removed.

FIG. 23.—Mason's Pin for Fractures of the Nasal Bones.

If the lower part of the nose is involved, or if the cartilage is detached or broken, it may be necessary to furnish some internal support. This may be done by means of a gutta-percha splint or a hollow vulcanized rubber tube, or by means of gauze wrapped around a piece of tubing, to permit air to pass through the nostril. Dressings of this kind must be removed and cleansed daily, and in all cases the patient should be enjoined from blowing the nose for the first ten days, during which time union usually takes place in a considerable degree. The nose should be cleansed daily with a normal salt or sodium-bicarbonate solution, or with a diluted antiseptic. Cobb's nasal splint is expensive, but is very satisfactory in preventing displacement either upward or downward. The splint is made of a band of steel which is fitted to the head, and to which are attached

an arm and a pad with screw adjustment. Coolidge has also suggested a splint, but it is not so practical as Cobb's.

If the fracture is internally compound, therefore involving the mucous membrane, it will be well to syringe the nasal cavity daily with boric-acid or salt solution, the head being held down in such a manner that the fluid will not run into the throat. The objection to internal support is that it irritates the mucous membrane and is a source of inconvenience. If the bony septum is displaced it must be restored by grasping it with a strong pair of forceps and twisting or turning it in the right direction; and, if it be found necessary to retain it in position, a special splint, pins, or a piece of vulcanized rubber may be used. If the lachrymal bone or the tear duct is involved, its patency must be secured by the daily introduction of a sterile probe or sound. Unless union takes place by the end of the third week, deformity is sure to occur. The formation of a hæmatoma of the septum must be relieved promptly.

Malar Bone and Zygomatic Arch.

The malar bone is only fractured by direct violence, and is rarely broken alone. Hamilton asserted that no uncomplicated case was on record. Single fractures are more rare than multiple, the rarest being a separation of the sutures with some splintering. Partial fractures involving the lower and outer part, or the margin of the orbit, have been observed, and so also has a fracture of the zygoma and the frontal process, extending into the bones with which they articulate. Fractures of the zygoma from violence from without are sometimes seen, and Stimson cites two cases that resulted from violence from within, by falling on the face with a stick in the mouth.

Diagnosis.—The diagnosis is based upon the visible deformity, the mobility of the injured part, and the existence of crepitus; the last two symptoms not always being obtainable. If there is not much inflammatory swelling, the deformity or flattening of the cheek is quite apparent, and palpation with the fingers, externally and inside the mouth, usually suffices to indicate the true nature of the injury. Protrusion of the eyeball may result from hemorrhage or from crushing inward of the bone. In fracture of the zygoma the presence of a blood-clot or the swollen condition of the tissues may limit the movement of the jaw or cause pain in chewing. Bleeding from the mouth or nose may result from extension of the fracture of the malar bone through the mucous membrane of the mouth or antrum.

Treatment.—If the fracture produces no deformity, no special measures of treatment are required. If deformity exists, an endeavor should be made to replace the fragments by manipulation with the fingers. In some cases it may be found necessary to make an incision and to replace the fractured bone by the aid of a blunt hook, a steel elevator, or a gimlet or screw carried into the

fragment. Fixation apparatus is not needed in fracture of the body of the bone. In fracture of the zygomatic arch, Matas, of New Orleans, advised the following mode of treatment: The patient being under the influence of a general anæsthetic, and all the necessary aseptic precautions having been taken, a long semicircular Hagedorn needle threaded with silk should be entered one inch above the displaced fragment, passed well into the temporal fossa, and made to come out half an inch below the arch. The silk thread is then utilized in drawing a silver wire around the bone, after which the bone is pulled into place and retained by securing the wire over a firm pad. The wire may be removed in about ten days. Fractures of the malar bone unite in the course of about three weeks, with the development of but little callus.

The Superior Maxilla.

Fractures of this bone may occur in connection with fracture of the malar and other bones that articulate with it. As these fractures, however, are the result of direct injury or violence, they are likely to manifest a great variety of conditions. Railroad injuries, gunshot wounds, the kick of a horse, falls and blows upon the face, and injuries in which the bone is more or less crushed are among the more common causes of fracture of the superior maxilla. The alveolar process may be partially or completely separated by blows upon it or on the teeth; and a blow beneath the nostril may separate the alveolar and palate processes, as well as the pterygoid plates, from the body of the bone. This fracture may be simple or compound; usually it is internally compound from tearing of the gums and mucous membrane.

Diagnosis.—The diagnosis, as a rule, is easily made by palpation, with one finger in the mouth and another on the outside. The degree of mobility, crepitus, deformity, and irregularity of outline may often readily be ascertained in this manner. Irregularity in the biting line of the teeth, when compared with the opposite side and the inferior maxilla, is diagnostic of the deformity incident to a fractured upper jaw. When the wall of the antrum is broken there will be a marked depression of the cheek. These fractures cause great swelling, pain, inability to chew, increased flow of saliva, and occasionally hemorrhage from injured branches of the internal maxillary artery. As these vessels lie in unyielding bony canals, secondary hemorrhage is not an unheard-of event. Injury to the infra-orbital nerve is by no means a rare occurrence, and the lachrymal duct may be involved. Ecchymosis of the hard or soft palate indicates fracture. Injury to the lachrymal canal may cause occlusion.

Treatment.—Repair takes place in from thirty to forty days—occasionally in less time—and the amount of callus formed is scanty. All fragments not absolutely or entirely detached should be left, as, owing to the great vascularity and vitality of the parts, extensive injuries often undergo complete

repair. In many cases the adjustment and retention of fragments may easily be accomplished without the aid of retention appliances. However, if there is a tendency for the fragments to drop down, a four-tailed bandage or a figure-of-8 head-and-chin bandage may be applied in such a manner as to permit of the introduction of fluid nourishment, while at the same time it holds the lower jaw firmly apposed to the upper. In some instances it will be well to have the assistance of a competent dental surgeon, in order to construct a suitable fixation apparatus. Gutta-percha, softened by immersion in warm water, may easily be moulded about the teeth of the opposing jaw, and held in place by a bandage carried about the head. As a rule, each case must be treated according to the peculiar features present. Fragments may be wired, and the teeth may be drawn together with wire so as to maintain the necessary adjustment. Great care must be taken each day to cleanse the mouth thoroughly with a detergent or antiseptic wash, as otherwise the secretions of the mouth may become quite offensive. Nutrition must be maintained for four or five weeks by fluid diet introduced between the solid portions of the interdental splints or in the vacancy left by a tooth that has been extracted at some previous time. The diet may also be introduced though a tube passed into the pharynx by way of the nostril or carried along the inner surface of the cheek behind a posterior molar tooth. Rapid repair is the usual result in these cases, and the degree of deformity that ultimately remains is remarkably small in many cases in which the injuries have been unusually severe. In fractures of the nasal, malar, and superior maxillary bones, the question of overcoming muscular contraction does not arise. If hemorrhage persists and threatens life, the external carotid will have to be tied, perhaps on both sides, before bleeding is finally arrested.

The Inferior Maxilla.

This bone, from its exposed and unprotected position, is more frequently fractured than are any of the other bones of the face. Fracture commonly involves the body of the bone, the most frequent site being near the canine tooth, between the symphysis and the mental foramen; but fracture may also occur in the rami or the condyles. Owing to the fact that the force which causes the injury is generally applied from outside, these fractures are often externally compound; but the presence of sharp edges or spicula and the close attachment of the mucous membrane to the bone render them internally compound. Fracture of the lower jaw has resulted from the extraction of teeth, and in some of these cases the only part that has been fractured has been the alveolar process. Blows or falls upon the chin frequently cause fracture of the body of the bone, and one or both condyles may be broken by blows on the cheek or chin. Comminuted fractures, except from severe injury and gunshot wounds, are rare, and double or triple fractures are not much more common. Fracture of the

coronoid process occurs very infrequently and is nearly always found in connection with injury of other facial bones. It may, however, be caused by direct concentrated violence. Fractures between the canine tooth and the symphysis are, as a rule, vertical; from this region back to the ramus, the line of fracture runs obliquely backward and downward, the anterior fragment being on the inner, and the posterior one on the outer, side, and the inferior dental nerve being sometimes torn or bruised. Owing to the great variety of injuries that may cause fracture of the inferior maxilla, a comprehensive, practical classification is scarcely feasible.

Diagnosis.—The distinguishing features of fractures of the lower jaw are: abnormal mobility; deformity, with imperfect alignment of the grinding surfaces of the teeth; pain at the seat of the injury; difficulty in mastication; crepitus; and hemorrhage. Corroborative evidence may be obtained by external and internal palpation, provided only a limited amount of soft tissue intervenes between the bone and the palpating finger.

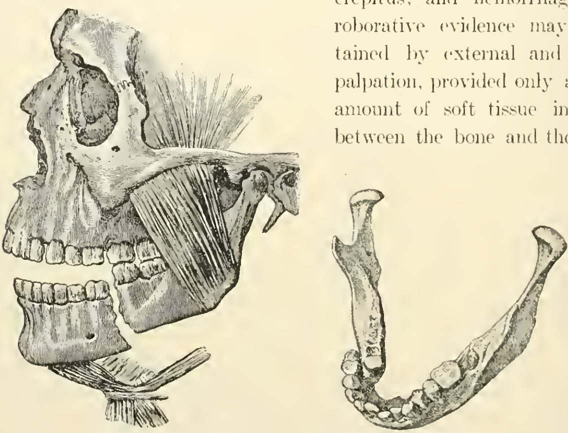


Fig. 24.—Displacement from Muscular Action following Fracture of the Lower Jaw. (Helferich.)

Swelling of the gums comes on rapidly. There will be dribbling of saliva, and in two or three days enlargement of the cervical lymph nodes, with early suppuration if the fracture is internally compound. In fractures of the body of the bone the anterior fragment may be drawn down by the digastricus, genio-hyoid, and genio-hyoglossus muscles. The posterior fragment will be drawn upward by the temporal muscle. If the neck of the condyle is broken, the jaw will point to the injured side, and the condyle will be pulled forward and inward by the external pterygoid muscle (Fig. 24).

Treatment.—In the treatment of extensive comminuted fractures of the lower jaw the assistance of a good mechanical dentist will be found desirable. In simple fracture of the body of the bone, with little deformity, it is generally sufficient to apply a simple pad to the chin and adjust snugly over it a four-tailed

Hamilton's, a Barton's, or a Gibson's bandage. Lateral pressure of the bandage may be prevented by placing beneath it pads over the temples and extending and stiffening the portion beneath the chin. A piece of gutta-percha, felt, or pasteboard, moulded to the part by first immersing it in hot water, padded lightly with cotton, and held in place by any of the bandages mentioned above, may be used for the purpose. These fractures unite in from four to six weeks, during the greater part of which time the movements of mastication must be enjoined rigidly, the patient being nourished by fluids introduced through a tube either by way of the mouth (in the manner described above) or through the nostril. If a tooth drops down between the fragments it should be removed, but it may immediately be replaced after the fracture has been adjusted. Teeth that are loosened should be pushed into place, and only those fragments of bone which are completely detached should be removed. If the

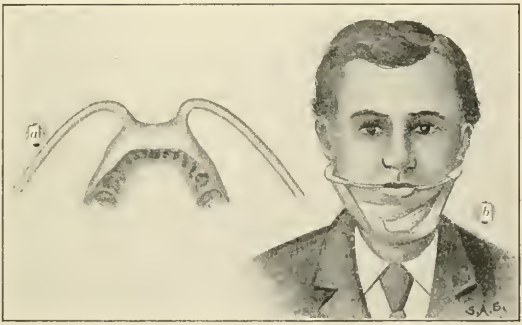


Fig. 25.—Kingsley's Splint for Fracture of the Lower Jaw. *a*, The splint itself; *b*, the splint applied.

teeth of either side of the line of fracture are firmly fixed, additional support and immobility can be secured by binding them together with silver wire. This step, however, is liable to be followed by loosening of the included teeth. The ideal treatment of fracture is by the interdental splint of Kingsley or Gibson. By this method a cast is made of the upper and lower portions of the mouth including the teeth, without adjustment of the fragments; breaking and setting the cast of the fractured bone by adjusting the grinding surfaces of the opposing teeth; then making an interdental gutta-percha splint that fits over the teeth of the rectified cast into which the teeth of the fractured jaw are forced and held by wire or thread or perhaps by an arm escaping at each angle of the mouth. A correct alignment of the grinding surfaces of the teeth is thus secured.

In internally compound fractures great care should be taken to keep the mouth cleansed daily by means of a detergent or an antiseptic wash, such as

hydrogen peroxide, followed by boric acid or normal salt solution. If there is much comminution, or if, from any cause, there is great difficulty in securing apposition and immobility, it may be found necessary to employ interdental splints of gutta-percha, hard rubber, or metal properly moulded and fitted, or to wire the teeth, or, possibly, to drill into and wire the fragments of bone. The teeth on either side of the fracture may be wired together; or the teeth of both fragments of the lower jaw may be wired to the opposing teeth of the upper. In providing such measures of relief it is better to trust to the mechanical ingenuity of the surgeon and his dental assistant than to place any dependence upon special appliances to be found in the stock of an instrument dealer. I have obtained better results from improvised appliances that meet the particular needs of each case than from efforts made to adjust a fracture to any ready-made appliance. In a number of instances I have used Kingsley's apparatus or interdental splint (Fig. 25), the cases being of such a character as to justify the expense of having the splint made by a mechanical dentist. As to the details regarding the proper fitting of such a splint, consult the article on "Prosthesis in Relation to Oral Surgery," in Vol. V. In one case which came under my care, and in which there was a severe compound complicated fracture, involving both sides of the jaw and having no less than three lines of fracture on one side, the result obtained from the use of this splint was excellent, there remaining but little, if any, deformity. In another case, one of ununited fracture which had existed for some months, the result was also very good; union was perfect, but owing to the fact that the surfaces of the fractured ends of the bone had been freshened, both prior to and during operation, the jaw was not as full as before the injury. Consequently the grinding surfaces of corresponding teeth were not adjustable. This defect, however, was not sufficiently marked to justify one in speaking of it as an objectionable deformity. The alignment of the teeth was correct.

Fractures of the neck of the condyle sometimes occasion considerable difficulty. In addition to the usual symptoms of fracture, there are certain others which are distinctive of this particular variety: such as, for example, the ease with which the condyle can be pushed forward into the zygomatic fossa, the failure of the condyle to share in the movements of the jaw, and the almost constant displacement of this fragment upward and forward by the action of the external pterygoid. To effect the reduction of this fragment it may be necessary to pass the finger into the patient's mouth, along the inner side of the ramus, until the condyle is reached, and then to push it into place. When this has been accomplished, the jaw should be pressed forcibly upward until the fragments are apposed, and then the jaw should be rigidly immobilized. Not unfrequently compound fractures of this bone become promptly and extensively infected, followed by suppuration, abscess of the cheek and neck, and often quite extensive necrosis.

In almost all cases of fracture of the lower jaw, fixation appliances can be removed in about three weeks, reasonable precautions being taken during the following ten days to avoid any movements that will tax the newly consolidated but not definitively ossified bone.

Hyoid Bone, Larynx, and Trachea.

The hyoid bone is broken in rare instances, most frequently by judicial or suicidal hanging; next in frequency, by throttling by an adversary; and lastly, by falls upon a hard substance or by blows, the upper part of the neck receiving the impact. The effort of swallowing a large bolus of food is mentioned by Valsalva as having caused the separation of one of the major cornua from the body of the bone. In some instances the injury may be internally compound. Fracture of the hyoid bone has caused death.

Symptoms.—The symptoms are often severe: Sharp pain at the site of the bone, on swallowing or talking or on slight pressure, and swelling which soon makes its appearance in the region and which is due to extravasation of blood. Among the other symptoms sometimes observed are the following: Recognizable mobility of the fragments and some deformity; more or less hemorrhage from the mouth if the fracture is internally compound; inability of the patient to move the tongue without pain, and when attempts are made to depress it, or when he himself tries to protrude the organ, these attempts may produce paroxysms of dyspnœa and coughing; finally, water taken into the mouth may cause coughing and choking. In the presence of such conditions it may be found necessary from the beginning to introduce nutrient fluids into the stomach by an œsophageal tube.

In many instances the larynx is also involved, the symptoms indicative of the irritable state of this organ being then more marked. Palpation externally and with the fingers in the mouth aids in making the diagnosis. There may be slight, moist crepitus.

Treatment.—The treatment requires as complete restoration of the fragments to their natural position as possible, and, to effect this, various measures may be required. The patient should be strictly enjoined not to talk nor even to whisper for at least a week or more. Swallowing is specially objectionable. Food may be administered by way of the rectum at first, or, instead, fluids may be introduced into the stomach by the aid of an œsophageal tube. Warren and Gould ("International Text-Book of Surgery," Vol. I., 1902) suggest fixing the head by means of a broad collar, which should be made of canton flannel saturated with plaster of Paris, or of sole leather that has been softened by immersing in hot water. This collar should be fastened to the head and shoulders by appropriate bandaging. Another method is to place the patient flat on the back and then, by means of sand bags, pillows,

and cushions, to fix the head in a position between flexion and extension. Da Costa advises the employment of a pasteboard splint which is to be applied to the back of the neck and secured by suitably bandaging the head and shoulders. Œdema of the glottis or larynx may arise at any time, and, for the relief of this condition or of the spasmodic action which may possibly arise, immediate intubation or tracheotomy may become necessary; and if the indications for such interference should appear to be urgent, and especially if the patient is not within easy reach of the surgeon, it will not do to defer these measures for too long a time. Union of the fragments takes place in about four weeks.

Fracture of the laryngeal cartilages and the trachea often occurs in connection with, as well as independently of, fracture of the hyoid, and the two conditions may present many symptoms in common. For their differentiation the surgeon must depend upon inspection and palpation. Fracture of these cartilages occurs not infrequently in the aged, but is very rarely observed in childhood. The frothy, bloody expectoration, the convulsive coughing, the dyspnœa, and the aphonia are usually more marked than when the hyoid alone is involved; the pain, on the other hand, may not be so severe. In some cases the only symptom is a change of voice; and in others, of a more severe nature, the interference produced by the injury advances rapidly toward death from suffocation.

The *treatment* of the laryngeal or tracheal injuries calls for local applications such as will soothe the inflammatory action, and at the same time for absolute rest in the recumbent position. Tracheotomy or intubation may be imperative at any hour; and, if the former is resorted to, efforts should be made to overcome the displacement by the introduction of a probe or sound into the windpipe. Da Costa (*op. cit.*) says: "If the fragments will not remain reduced, introduce a Trendelenburg cannula or a tracheotomy tube, and pack gauze around it. Take out the packing in four days, and remove the tube as soon as the patient breathes well, when the opening may be allowed to close. In these cases keep the patient absolutely quiet. Union takes place in about four weeks."

The Sternum.

Fractures of the sternum, owing to the elasticity of its support by the ribs and costal cartilages, are quite rare, most of the cases occurring in adult or advanced life. While in nearly all cases the fracture is transverse, oblique fractures are next in frequency; instances of longitudinal fracture have been seen. A fracture of the sternum may be accompanied by fracture of the ribs and separation of the costal cartilages. The most frequent site of the fracture is the upper portion of the sternum, between the second and fourth cartilages. The connection of the manubrium with the gladiolus being of the nature of an articulation until adult age, prior to this time the separation of

the two parts may be looked upon more properly as a dislocation or diastasis. This separation, however, is to all intents and purposes a fracture, and will therefore not be treated as a lesion that calls for separate consideration.

Fractures of the sternum may be simple or compound, complete or incomplete, and single, multiple, or comminuted. Direct violence is by far the most frequent cause, yet indirect force has produced fractures of this bone, and in rare instances muscular contraction alone has sufficed to produce the lesion. Gunshot and punctured injuries are among the most frequent causes of compound fractures. Separation of the ensiform cartilage is quite rare.

The complications are fractures of ribs, etc., injury to the pleura, pericardium, lungs, or heart, and hemorrhage into the anterior mediastinum; later, abscess and necrosis may occur. The prognosis is favorable in the absence of serious internal lesions or sequelæ, and union, either bony or fibrous, takes place in from five to eight weeks.

Symptoms and Diagnosis.—The history of the injury should be carefully elicited. If the bone is fractured there should be mobility of the fragments under pressure, during respiration, and on changing the position of the body, attended by crepitus. The position assumed by the patient is with the head and body flexed forward. Displacement may, in many instances, be lacking. When it does exist, however, it is a characteristic sign, especially in transverse fractures, in which it can be seen that the lower fragment projects forward and possibly overrides the upper. Pain (which is more or less localized and which may be increased by respiratory and other movements) and cough are usually present. Stimson (*op. cit.*) says: "I have seen a few cases in which the only symptom was pain on pressure, with late ecchymosis." If—as happens only in rare cases—the internal mammary vessels are torn, hemorrhage into the anterior mediastinum may be sufficient to affect the action of the heart or even cause early death.

Treatment.—The displacement should be corrected, if possible, by careful manipulation, which may be aided by bending the body back over a firm pillow and causing the patient to take a full inspiration. The displacement may recur, or it may be impossible to reduce it by any of the means just enumerated. In the latter event, it is not wise to resort to such operative measures as elevation of the bone by means of hooks, screws, gimlet, etc., since these agents may be inefficient in action, the restoration transient, and in any event attended with quite needless exposure. Furthermore, union will take place and the existence of a deformity is not in this situation a matter of special cosmetic importance in the male. Having adjusted the fragments as well as possible, in transverse and oblique fractures, apply a broad strip of adhesive plaster from the top of the manubrium to the xiphoid end of the bone, and place over this, from one axillary line to the other, a series of transverse strips, thus making a complete encasement of the anterior surface of the chest.

Then, over this, snugly adjust a broad bandage, securing it with safety-pins or eyelets and lacing, so as to restrict the chest movements as much as is advisable. Straps over the shoulders may be attached to keep the bandage from slipping down. The adhesive plaster should be removed at least once a week and the whole surface of the chest thoroughly cleansed. It will not be necessary to continue this mode of treatment beyond a period of four weeks. In some cases it may be found desirable to apply a figure-of-8 bandage over the circular, as an additional means of maintaining the adjustment of the fragments. Rest in bed for the first three or four weeks is advisable, and a half-sitting position, with a pillow between the shoulders, will be found the most comfortable. The complications of hemorrhage into the anterior mediastinum or of suppuration require active interference. In the case of hemorrhage, immediate control of the bleeding vessels is necessary; and when suppuration occurs, which is indicated by œdema of the anterior surface of the chest and by the presence of fever, it will be necessary to adopt such operative procedures as will secure thorough drainage. In the treatment of compound fractures the established measures of wound treatment must be supplemented by efforts to secure as absolute rest of the parts as may be possible. Ordinarily, separation of the ensiform cartilage requires no treatment, but if it produces continued pain or discomfort it may be exposed and removed.

The Ribs.

Fracture of the ribs occurs more often than fracture of the sternum, but not so frequently as fracture of other long bones. Dr. L. S. Pilcher, in the "International Text-Book of Surgery," states, as the result of his observation at the Methodist Episcopal Hospital of Brooklyn, that fracture of the ribs occurs about one-half as often as fracture of the femur. The shortness, the higher degree of curvature, the position, etc., of the three upper ribs, and the shortness and greater elasticity of the two lower ones, both of which are fixed only at one end, render these upper and lower ribs less liable to fracture than the other seven; and the seventh rib, because of its comparatively great length and exposed situation, is more often broken than any other. In some instances one rib alone is the seat of one or more fractures, in other instances a number of ribs on one or both sides may be broken at the same time. Fractures of a rib are rarely seen in childhood; they are oftenest observed in males. A fracture of a rib results most frequently from a direct force, but occasionally it is due to the action of an indirect force, as when the chest is caught between opposing bodies. In a few instances the fracture has been produced by muscular contraction alone, as by coughing, sneezing, and lifting heavy weights, or by some sudden movement of the body, as simply turning in bed. Gross reports the case of a lady of seventy-four who had the eleventh

rib on the left side broken by her granddaughter, a stout girl of fourteen, embracing her; he also states that he had seen one case in which eight ribs were fractured on one side at the same time, and he refers to the fact that in his collection there is a specimen that shows fifty-nine separate fractures of the ribs—twenty-seven on the right and thirty-two on the left side. This specimen had been taken from the body of a woman over seventy who had thrown herself from a second-story window. As regards the nature of the violence Dr. Pilcher (*op. cit.*) gives the facts in twenty-five cases of which he had kept a record. They are as follows: 9 from falls from a height; 7 from railroad accidents; 4 run over by a wagon; 2 injured by a falling body; 2 by being run over or kicked by a horse; and 1 crushed by machinery.

Symptoms and Diagnosis.—The symptoms may be limited and indefinite, or characteristic and well marked; a definite diagnosis being perhaps impossible in a partial fracture. Abnormal mobility may be present, but it cannot always be demonstrated on account of the elasticity or the movements of the ribs. It is best detected by pressing with the finger tips alternately on either side of the supposed site. Crepitus is not always present, but may be detected by careful palpation and auscultation, especially during respiratory movement. Pain is sharp (a "stitch" in the side), localized and increased by pressure, by movements of respiration, by sneezing, etc.; and the fact that pressure upon the sternum or upon the rib at a distance from the supposed site of the fracture produces pain at the latter point is regarded as important. Cutaneous emphysema is diagnostic of fracture of the rib, provided there be no other wound that might produce it. Bloody expectoration may or may not be present in fracture of the rib complicated with perforation of the lung; and this symptom may also be due to a complicating injury when no fracture exists. Displacement of the fragments upward or downward may be observed, or there may be either an outward or an inward angularity, which will be increased by pressure on the sternum; but overlapping of the ends is obviated by the continuity of the unbroken ribs above and below. Overlapping, however, may be observed in cases in which a number of ribs are broken. The broken ends of a fractured rib may be separated, or a fragment may be displaced in such a manner as to leave a gap through which a pulmonic hernia may develop.

Prognosis and Complications.—The prognosis is good as regards the healing of the fractured rib, union of the ends of the broken bone being promptly effected. When superabundant callus is formed or when great displacement of the fragments takes place, two or more ribs may become fused together. In a few instances fibrous union has been reported. The late Dr. Paul F. Eve reported, in the *New York Medical Journal*, Vol. XV., a case of non-union due to necrosis. The pulmonic and pleural complications which are observed in the aged and feeble, independently of, or in connection with, fractures of the ribs, are apt to be of a serious nature and

may occasionally prove fatal. Superficial emphysema may be slight and transient, or it may continue for a number of days and may extend over a large portion of the body, requiring free incision to secure escape of the air and to prevent embarrassment of breathing. Pneumothorax, hæmothorax, pneumonia, and pleurisy are indicated by the corresponding physical and rational signs and symptoms and must be anticipated and promptly determined. When air escapes into the pleural cavity, as the result of a laceration of the lung, it is likely to become a source of danger especially when it compresses the sound lung. When this occurs it may be found necessary to establish a vent by incision. Intrapleural hemorrhage is due in most cases to lacerated lung tissue, but it may also be due to injury of the intercostal or mammary vessels. When, even in an apparently simple fracture of one or more ribs, feebleness of the pulse, rapidly developing anæmia, and dyspnœa, together with the physical signs, warrant the belief that severe internal hemorrhage is in progress, the surgeon is justified in converting the simple fracture into a compound one by incision, removing a portion of one or more ribs, exposing and controlling the bleeding vessel, and, perhaps, removing the accumulated blood from the pleural cavity. In the case of serous or sero-sanguinolent effusion, attended by threatening symptoms of lung consolidation, or infection and suppuration, it will be found necessary to adopt special measures of treatment. Persistent hemorrhage from torn lung tissue is difficult of recognition, and, according to Stimson (*op. cit.*), the bleeding vessel cannot be reached even if its existence should be certainly ascertained. He suggests constricting the thigh at the groin with rubber tubing or a roller bandage in such a manner as to arrest the venous current in the limb, thus causing the withdrawal of a considerable amount of blood temporarily from the circulation and so permitting or favoring the formation of a blood-clot. In such cases the pressure of the accumulating blood may be utilized to arrest the bleeding when the circumstances of the case justify the delay. In threatened pulmonary engorgement with extreme dyspnœa, he advises general venesection and quotes Mr. Bryant as having recommended it unhesitatingly and forcibly. The flow of blood following the venesection should be arrested as soon as relief is obtained, for syncope can only do harm.

Other complications are injury to the pericardium, heart, spleen, liver, colon, etc.

Treatment.—The treatment of a fractured rib is in itself quite simple, but the measures required are somewhat varied in character according to the nature of the fracture. In the majority of instances little or no deformity is present. In a simple case with deformity, replacement of the fragments by manipulation will probably suffice. In outward angularity direct pressure may be required. In inward angularity it is best to make pressure on the sternum, or, as suggested by Da Costa (*op. cit.*), anæsthetize with ether, as the "full

inspirations under anæsthesia may force the fragments outward." If these means fail, however, and if, on account of pain or for some other reason, reduction seems to be imperative, a hook, introduced through an incision in the skin, may be passed around the rib and utilized in bringing the fractured ends of the bone into apposition. The mobility of the chest wall is then to be restricted by means of strips of adhesive plaster, which should encircle it and at the same time pass over the fracture, care being taken to apply the strips during full expiration and to make them overlap like the shingles of a house. Over this, there may be applied a broad circular bandage, which should be firmly and tightly fastened by means of safety pins or by eyelets and lacing, with shoulder straps to prevent it from slipping down. The object aimed at in this procedure is to restrict pulmonary respiration. The region of the ensiform cartilage must not be encroached on by the adhesive strips or by the bandage. The strips of plaster must be removed once a week and the surface cleansed. Malgaigne recommends, in the event of circular constriction being found objectionable, that a narrow strip of adhesive plaster be carried from the anterior end of the seventh rib, on the right side, across the front of the chest, under the left arm, and across the back to and over the right shoulder, then again across the chest in front and around the left side and back to the end of the crest of the right ilium. This immobilizes the left (fractured) side of the chest, leaving the right free. When an upper rib is fractured the respiratory movements can be controlled by encircling the thorax with adhesive plaster at a point below it, preferably as nearly as possible over the site of the attachments of the diaphragm; strips of plaster may also be applied obliquely over the seat of the fracture.

In strapping the chest for fractured rib, two points should be particularly noted, viz.: (1) The straps should be passed just beyond the median line in front and behind; (2) they should be applied in full expiration. One or two straps passed over the shoulder help much to secure immobilization.

The Costal Cartilages.

Fracture of the costal cartilages, even in the aged, is quite rare; it may occur at any point, but is observed most frequently at the junction with the rib or at that with the sternum. The fracture may be double, or several cartilages may be involved. In single fractures the eighth cartilage is the one most frequently broken. The cause in most cases is direct force, although it has also been produced by muscular contraction. It is rarely, if ever, the result of indirect force unless accompanied by other injury.

Localized pain with ecchymosis is the only constant symptom. Deformity or displacement, if present, is either in a backward or in a forward direction. Mobility may or may not be present. Crepitus is not often found.

The treatment is similar to that of a fractured rib, it being permissible to remove the dressings in four weeks. Malgaigne suggested the application of a truss. Osseo-fibrous or fibrous union commonly results, and, even though perfect apposition be not secured, callus may form around or between the ends, and ossification subsequently take place.

The Clavicle.

The clavicle is long and slender, with two distinct curvatures in opposite directions. It acts as a brace or stay to the shoulder, maintaining it upward, outward, and backward. For this reason and from its exposed position, it is quite frequently broken. Malgaigne gives 228 cases in 2,358 fractures of different bones of the body. Gross *(op. cit.)* estimates the proportion at nearly one-tenth; other writers fixing the frequency at 15 per cent and 16 per cent. From one-third to one-half of the cases occur in children under the tenth year of age, some authorities giving it as the most common of all fractures. In adult life it is found most often in males. In most cases the fracture is single and simple: it may also be complete or incomplete, the latter especially in children. Sometimes it is multiple, or comminuted, but rarely compound or complicated unless from some direct force such as is exerted in gunshot and other wounds, punctured or lacerated. Fracture of both bones may happen.

Fracture most often occurs at the outer half of the middle third of the bone or at the junction of the middle and outer thirds. It occurs next in frequency within the limits of the outer third, and lastly at the sternal end. In children the fracture may be transverse, but in adults, and especially when the fracture occurs at the most frequent site, it is directed obliquely inward, downward, and backward. As a rule, the inner fragment overlaps and overrides the outer, it being perhaps drawn upward by the sterno-cleido-mastoid muscle; and the outer fragment, being acted on by the pectoralis minor indirectly and the subclavius, but mainly influenced by the weight of the arm and shoulder, is displaced downward and inward. The fracture in adults may be transverse if due to direct violence (Fig. 26).

Fractures of the clavicle are most frequently caused by indirect violence, as by falling on the shoulder or on the extended hand, the bone giving way at its thinnest or most vulnerable part. They are produced by direct force, and occasionally also by muscular contraction. When the combined action of the pectoralis major, the deltoid, and other muscles is suddenly applied to the clavicle, while at the same time the shoulder and scapula are brought forward by the serratus magnus, fracture may be caused.

Symptoms.—The symptoms in most cases, especially those of complete fracture, are characteristic. The patient generally bends the head and neck toward the injury, and supports the elbow or wrist in the hand of the opposite side, at

the same time keeping the arm and forearm closely to the chest. It will also be observed that the shoulder, on the same side as the injury, is nearer the sternum, the bone sometimes being shortened at least an inch, the outer fragment lying on a lower level, without the spinal column being flexed. Preternatural mobility and crepitus may be elicited by forcing the shoulder back, but these symptoms may be absent in the incomplete fractures of childhood. Since the bone is located so near the surface, usually displacement may be readily detected by careful palpation. There is considerable pain on motion and when pressure is made on the site of the injury, and the mere weight of the unsupported limb may cause pain. Localized pain on pressure, and when the shoulder is carefully pressed inward, is a sign of incomplete fracture, and, combined with ecchymosis, it may be the only one noted at the time of the accident. At the end of a week, however, the presence of a firm callus at the site of injury will confirm the diagnosis. Interference with function is due to pain on movement and loss of bony support. The patient, on being requested to place his hand on his head, will be most apt to flex the head toward the hand rather than raise the latter except with the aid of the uninjured fellow. Displacement is less marked in fractures of the inner and outer thirds of the bone. In the least frequent variety of fracture—that of the inner or sternal third—the displacement may be in any direction, most frequently due to direct force. As a rule, however, the inner end of the outer fragment is displaced downward and forward, or, when both ends are not completely separated, they are drawn downward and forward. This deformity is due to the action of the pectoralis major and deltoid muscles, and is present when the bone is broken here by muscular contraction (Fig. 27). In transverse fracture in this part of the clavicle, lateral displacement may be slight or wanting. In fracture of the outer third the line is mostly transverse, and the displacement may be slight, wanting, or quite noticeable. The displacement here is generally angular, with the apex directed backward. When the fracture is external to the trapezoid ligament or at the outer inch of the clavicle, angular displacement is the rule, the outer fragment looking forward and inward, until it stands at a right angle with the remaining bone. The fractured surface of the external fragment may lie against the an-

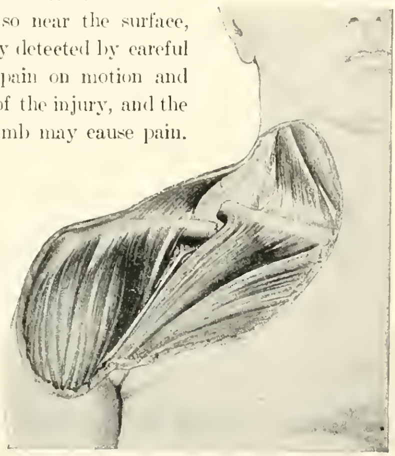


FIG. 26.—Fracture of the Right Clavicle. (Anger.)

terior border of the inner fragment or under it. Differentiation from a dislocation of the acromial end of the clavicle depends much upon the existence of crepitus, to demonstrate which, however, may be no easy task. When, however, fracture takes place inside the attachment of the trapezoid ligament—*i.e.*, between the conoid and trapezoid divisions of the coraco-clavicular liga-

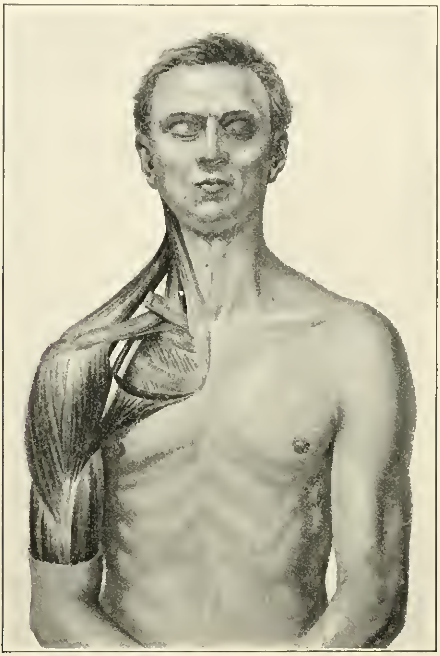


Fig. 27.—Fracture of the Clavicle with Typical Displacement. The site of fracture is at the junction of the inner and middle thirds of the bone. The inner fragment appears to be drawn upward by the contraction of the sterno-cleido-mastoid muscle, or pushed in the same direction by the outer fragment. The great pectoral muscle has been partly removed, and the axillary space (considerably narrowed by the dislocated head of the humerus) is thus exposed. The shoulder and arm are depressed. (Helferich.)

ment—little or no displacement can be found, because these ligamentous structures hold the fragment well in place.

Multiple fractures of the clavicle are, as a rule, due to direct violence. The bone, however, has been known to break in two places as a result of indirect violence. When one fracture is at the acromial end and the other at the sternal or the middle division, the displacement of the intervening fragment is but slight; but, when the lines of fracture are both in or very near the middle section, the displacement is likely to be quite marked.

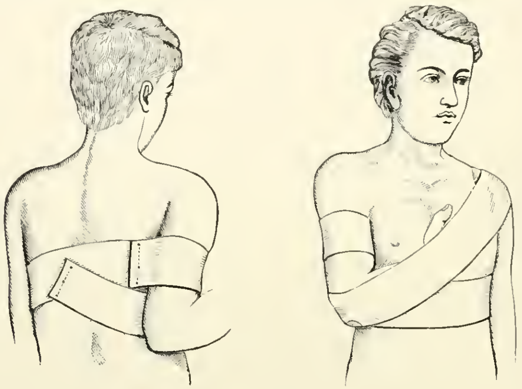
Fractures of the clavicle readily unite in about four or five weeks; but, unfortunately, as a rule, with some deformity, due to shortening or angularity or to both. A surgeon should not promise a perfect result, either anatomical or functional. The discomfort attending any perfectly immobilizing dressing will be felt by all patients. A good functional result is more apt to be secured than a cosmetic one, and many failures in this respect may occur notwithstanding the exercise of the greatest care on the part of the patient, the attendants, and the surgeon.

Complications.—Complications involving the large blood-vessels in the vicinity of the fracture almost exclusively belong to compound injuries caused by gunshot and lacerated and punctured wounds. However, a few cases of injury to important neighboring soft parts have been reported in simple fractures of the clavicle: such as injuries to the subclavian and internal jugular vessels; injuries to the brachial plexus from sharp ends of fragments and the harm resulting from the mere pressure exerted by such fragments and by enclosing or exuberant callus. In rare instances the dome of the pleura has been injured: but thoracic complications are almost entirely limited to fractures of the clavicle associated with fracture of one or more ribs.

Treatment.—In the treatment of fracture of the clavicle three important principles should be carried out, viz., to keep the shoulder pressed *upward, outward*, and *backward* until the broken support, the clavicle, undergoes repair. The shoulder resembles in some respects a builder's portable derrick, with two rigid supports, the clavicle and the scapula, which are held in position by muscular stays or guys. The clavicle, from its peculiar shape and slender form, with muscular attachments at different points pulling in different directions, is readily broken, and is difficult to maintain in adjustment until splicing by callus is perfected. Since the days of Hippocrates earnest and able surgeons in all lands have wrestled with this problem, and a vast number of different devices have been suggested for carrying out the above three paramount indications. While none of these devices is able to fulfil the desired purpose perfectly, some of them have proved fairly satisfactory. In the following description only those devices which in my opinion come nearest to success in this respect will be considered.

In my experience no measure has given so good results as the plan suggested ages ago by the "Sage of Cos," viz., keeping the patient for a sufficiently long time in the supine position. Many patients will refuse to be thus confined for three or four weeks, and in some cases it will not be advisable—on account of the patient's age or for other reasons—to adopt this plan of treatment; but, when these difficulties are not in the way, the results obtained will be found most satisfactory. Especially is this true in the case of young females, in whom a cosmetic result is of great importance to all concerned. The best plan is to place the patient on the back on a firm mattress, with a thin pillow between the

shoulders, and the head elevated sufficiently to relax in some slight degree the sterno-cleido-mastoid muscle, the attainment of which purpose will be further promoted by placing the bed in such a position that the face shall turn preferably to the injured side. The forearm should be lightly confined across the chest with a sling, a small bag of shot should be laid over the site of the fracture, and sand bags should be placed along the sides of the body to maintain the supine position continuously for the time required. A small pad should be kept in the axilla to maintain the normal axillary space, and the arm should be confined



a

FIG. 28.—Sayre's Dressing for Fractured Clavicle. *a*, First strap; *b*, first and second straps.

to the chest with a single turn of a roller bandage. The elbow should be raised slightly by means of a cushion, to aid in keeping the shoulder pushed upward and backward.

Sayre's dressing (Fig. 28) is widely used in this country and elsewhere. I would lay stress upon the importance of joining with it the employment of an appropriate axillary pad. Such a pad, made of horsehair or wool, covered with muslin, should measure 6 inches long, 5 inches wide, and from $1\frac{1}{2}$ to 1 inch thick at the base; it should have a firm consistence, should be placed well up in the axilla, with the apex directed downward, and should be secured in place by strips passing over either shoulder. Sayre's dressing is applied as follows: The surgeon, standing behind the patient, reduces the fracture by pulling the shoulders firmly backward and upward. An assistant, taking the end of a long strip of mole-skin adhesive plaster, three to four inches wide, adjusts it around the middle of the arm of the same side as the fracture, with the adhesive surface next to the skin and secured with pins or stitches so as not to cause any constriction. The elbow is then drawn well back and the plaster is carried backward around the body, across the chest and side, and

its adhesive surface smoothly applied to the skin. This strip of plaster serves as a fulcrum, dividing the arm into the upper and lower arms of a lever. A second longer and broader strip is next anchored at one end to the upper and anterior surface of the shoulder of the uninjured side, then carried obliquely backward and downward across the point of the elbow of the injured side, thence firmly in an obliquely upward direction along the outer and ulnar surface of the flexed forearm and extended hand, so as to permit of its attachment to the chest wall, and to the anchorage of the plaster on the opposite shoulder. This strip mechanically carries backward and upward and holds there the upper arm of the lever before mentioned, which correspondingly carries and holds upward and backward the shoulder of the injured side, thus rectifying the deformity of the fractured clavicle of that side. The oblique direction of this strip of plaster makes a fulcrum of the side of the thorax which carries the shoulder outward. The hand and forearm are then confined to the plaster strip by means of narrow strips of the same carried thence at suitable intervals.

Some modifications of this method are practised, such as: the carrying of a third broad strip of plaster firmly around the external surface of the elbow and body, with the idea of increasing and maintaining the outward position of the shoulder by correspondingly increasing the power of the lever controlling it; also the anchoring of this strip of plaster to the chest in front, below the sound clavicle, and then carrying it obliquely backward and downward across the point of the elbow, thence obliquely upward to the anchorage and posterior surface of the scapula, to all of which it is made firmly adherent (Eve). At all points of undue pressure and between opposed surfaces—especially at the point of the elbow, at which still further security of attachment is gained by making a slit in the plaster—proper padding should be interposed. When axillary pads are inserted care should be exercised that undue pressure be not made on the axillary vessels and nerves. The application of a muslin bandage over this dressing (Velpeau), for the purpose of meeting the same indications, is favored by some surgeons.


Fig. 29.—Velpeau's Bandage.

The seat of the fracture should be lightly covered to protect it against being disturbed, but local pressure for correction purposes is no part of the Sayre method of treatment, and, if employed, should be carefully observed, in order that any objectionable effects from undue pressure may be at once obviated. This dressing may require removal once a week, when the surface should be thoroughly cleansed with soap and alcohol; it should be worn about four weeks. Excoriations are to be treated in the usual manner.

I have found Sayre's dressing to be very effective. Occasionally I have used satisfactorily two pieces of strong muslin in place of the long adhesive strips.

The time-honored *Velpeau's bandage* (Fig. 29), so long regarded as classic, I have found very serviceable. It is rendered more effective, I believe, by the employment of an axillary pad, applied with the precautions mentioned above. In children and even in restless adults, it may be found advantageous to fortify it with a thin layer of plaster of Paris, silicate of sodium, or starch, which will render it more permanent. Velpeau's bandage is simple, meeting the three important indications of treatment.

Mayor's scarf or *sling* also has its advocates. Stimson (*op. cit.*) briefly describes it as follows: "It is made of a square of muslin the diagonal of which is long enough to extend easily around the body. The forearm is flexed at an angle and laid across the breast; the cloth, folded diagonally, is laid over it and tied around the body so that its folded border runs horizontally around, an inch or two above the forearm, in front of which the cloth hangs down. The free point of the triangle is then brought up between the forearm and the body, and the two folds of which it is composed are secured, one on either side of the neck, by bands attached to the scarf behind and brought over the shoulder; or the forearm is placed between the folds of the triangle, the folded diagonal of which forms the lowest part of the dressing, while its ends are tied around the body as before. The folds that form the third point are tied together about the neck.

"This method is suitable for fractures without much displacement, especially for those in children without torn periosteum."

In incomplete fractures in children, a simple sling supporting well the elbow will often suffice. It is better, however, to let the fracture remain unreduced, rather than to resort to heroic measures; nature being relied upon to remove the deformity, as she so often does. In the adult, exposure of the seat of injury by incision may be necessary in rare cases in which other measures have failed suitably to overcome the deformity, or where it is very important to relieve it because blood-vessels or nerves are being pressed upon, or because the skin threatens to give way. It is possible, by incision, to adjust the fragments and secure them by silver wire or chromicized-gut suture. In delayed union or in non-union the liability of deformity or of loss of function justifies the resort to suturing. In fracture at the outer end of the clavicle, reduction is accomplished by pulling the shoulders firmly and forcibly backward, in which position they may be maintained by a figure-of-8 bandage crossing posteriorly. If the fracture is external to the coraco-clavicular ligament, it may demand the employment of wire or chromicized-gut suture. Fractures at the sternal end may require similar measures of treatment. The late Dr. Paul F. Eve was the first to cut down on and wire a fractured clavicle; he resorted to this method in a

number of instances, especially in young females, in whom it is important to secure a good cosmetic result. When wiring is practised in this class of cases it is especially needful that the strictest demands of aseptic treatment be heeded, otherwise suppuration and possibly necrosis will contribute their disfiguring influences to the final outcome.

A more or less stiffened shoulder joint may follow fracture of the clavicle. If passive movements fail to relieve it, the administration of a general anæsthetic and the use of force may be required. Ossification of the coraco-clavicular ligament or the presence of masses of callus may impair movement of the acromio-clavicular joint. In still other cases loss of function may arise from nerve injury.

The Scapula.

Fractures of the scapula occur in from 0.8 to 1 per cent of all fractures, the infrequency being attributed to its great mobility and the elasticity of its support. The following classification is, I believe, sufficient for all practical purposes: 1. Fracture of the body. 2. Fracture of the surgical neck. 3. Fracture of the glenoid fossa. 4. Fracture of the coracoid process. And 5. Fracture of the acromion process.

Nearly all of these fractures are due to direct violence, and they occur most frequently in adult males.

Fracture of the body, which results always from direct injury, may extend in any direction. Such fractures may be simple, multiple, or comminuted. There may be little displacement, the line of fracture being discoverable along the spine of the bone as well as along its anterior border. If this line extends across the bone below the spine, the lower fragment may be displaced forward and upward by the teres minor and major and serratus magnus muscles. Union, with a limited amount of callus, may be expected in the course of about four weeks.

The symptoms are pain, increased by rotating the bone, crepitus, and ecchymosis; and abnormal mobility can in some instances be detected, especially if the shoulder is steadied and the lower angle of the bone is lifted. If, in the normal state of the parts, the arm be carried behind the body, the inferior angle of the scapula will be tilted to such a marked degree that one may readily grasp it. In fracture the tilting will be lessened by the act, and, when the angle is grasped and moved, a false point of motion and perhaps crepitus will be noted. Careful inspection and palpation over the bone, along the spine and the anterior border, will aid in diagnosis, especially if they be combined with moving the inferior angle.

The treatment consists of a "shoulder cap, or a gutta-percha splint moulded over the scapula, the arm bound to the side and the hand carried in a sling" (Da Costa), or "a sling for the arm is often sufficient; a three-tailed piece of

strapping, one end carried over the shoulder, and the other two around the chest, is sometimes used to press and fix the scapula against the thorax." (Treves.)

Fracture of the surgical neck (Fig. 30) results from a blow or a fall upon the shoulder, the fragment consisting of the glenoid cavity and coracoid process, with the attachments of the pectoralis minor, the coraco-brachialis, both heads of the biceps, and the long head of the triceps muscles.

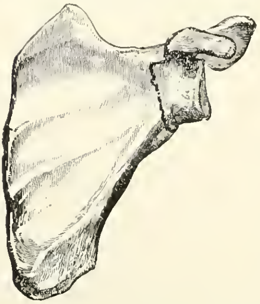


Fig. 30.—Fracture of the Neck of the Scapula. (H. Rieffel, in Le Dentu et Delbet: "Traité de Chirurgie.")

In this variety of fracture the shoulder is flattened, the acromion unduly prominent, the arm lengthened, and the elbow at the side, while the lower fragment may be felt as a mass in the axilla; but the ease with which reduction may be effected and with which a recurrence takes place should differentiate the condition from a dislocation. The deformity will disappear on grasping the arm and pressing it upward, and there will be pain, abnormal mobility, and crepitus.

Fracture of the anatomical neck alone has not been observed.

As regards the treatment, the lower fragment needs to be carried outward, backward, and upward. The use of a Velpeau roller has also given satisfactory results. The dressing may be left off in four weeks.

It is thus observed that the indications are similar to those in fracture of the clavicle, and therefore the condition may be cautiously treated in a similar manner, or as one would treat dislocation of the acromion end of the clavicle.

Fracture of the glenoid fossa is caused by a direct force driving the head of the humerus against it. In the majority of cases the fracture is limited to the inner border, but occasionally the outer or lower border is broken off. The fracture may be stellate, the lines running in any direction across the articular surface. Dislocation usually accompanies the chipping-off of the anterior lip.

It is quite a difficult matter to diagnose a fracture of the glenoid fossa. The fragment may be felt by careful palpation in the axilla, with manipulation of the limb. Crepitus may be elicited by extending the arm at a right angle and pressing the head of the bone against the opposing surface. In some cases, however, there may be no very definite symptoms.

The indications for treatment are practically the same as those of fracture of the neck of the scapula or of a dislocation of the shoulder, the only difference being that, to secure a proper adjustment, greater care is required than in a dislocation.

Fracture of the coracoid process occurs rarely, and usually the violence causing it is so great that adjoining structures are injured. It is commonly due to

direct violence, although cases have been observed in which the tip has been separated by muscular contraction. The dense, fibrous tissues around this portion of the scapula prevent much displacement by muscular action. Mobility and crepitus may be detected by pressure on the tip of the process when the muscles arising from it are relaxed. Pain is increased by contraction of the muscles attached to it, viz., the pectoralis minor, the short head of the biceps, and the coraco-brachialis.

The use of a Velpeau bandage or a sling until pain subsides constitutes the best treatment. The muscles last mentioned should be in a relaxed state during treatment. In fracture of the tip, fibrous union will result.

Fracture of the acromion process is caused by direct force, as by a blow or a fall on the shoulder, and by muscular violence. The line of fracture may be oblique or perpendicular to the articular end.

The symptoms are pain, flattening of the shoulder, mobility, inability to abduct the arm, and crepitus. Crepitus is best elicited by abducting the arm; and mobility may be ascertained by careful palpation with the fingers of one hand, while the other manipulates the limb. Inability to raise the arm is common in this injury, and rotation is painful. If the portion of the process in front of the acromio-clavicular junction is broken, the position and relation of the arm to the body will be but little changed; but if the line of fracture is through the articulation or behind it, the shoulder will be disposed to fall forward, inward, and downward.

Fibrous union is the rule, bony union the exception. The following method of treatment I regard as the best: "If the injury is anterior to the acromio-clavicular articulation, a wedge-shaped pad (at least 6 by 5 inches, and 3 inches thick at the base, I prefer) is placed in the axilla with the apex upward, and the arm confined to the chest with a sling and roller. If the line of fracture is through or back of this articulation, the fixation appliance for fractured clavicle will be required." (Hamilton.) A triangular-shaped frame of wood or wire, when padded and fastened in place, with the apex in the axilla and the base below, and of such length as completely to relax the middle fibres of the deltoid, is an excellent apparatus for this purpose.

The Humerus.

Fractures of the humerus are of great importance, owing to the functions of the bone and the difficulties which are encountered both in diagnosis and in treatment. Different observers and different statistics furnish data which vary considerably as to the frequency of fractures of this bone and their locations. All agree, however, that the humerus is most frequently broken in the first twenty years of life. Stimson places the frequency of occurrence of fractures in this bone at less than 4 per cent of all fractures, while Treves makes it 7.5

per cent. He further says: "They diminish in frequency with each decennium. In the first, fractures of the lower extremity predominate over fractures of the shaft, and fractures of the upper end are few; from ten to twenty years the same order holds, but the differences are less marked, injuries of the upper end being much more common. Injuries of the lower end now fall off, and disappear in the highest periods: but those of the upper end increase relatively to those of the shaft, until, in advanced age, they become the commonest fractures of the bone."

A consideration of fractures of this bone naturally suggests a division into three grand groups, viz., those of the shoulder or upper extremity of the bone, those of the shaft or body of the bone, and those of the lower extremity or elbow. The injuries that occur in these divisions present marked differences as regards the manner in which they are produced, the course which they pur-

Fig. 31.—Fractures of the Upper End of the Humerus. (Schreiber.) *a*, Lines of fracture in the upper end of the humerus (1, Fracture of the anatomical neck; 2, fracture through the tubercles; 3, fracture of the surgical neck); *b*, fracture of the humerus below the tubercles, with abduction of the arm and impaction of the fractured ends of the bone. View from in front; *c*, fracture extending through the tubercles and also across the anatomical neck of the humerus (Y-shaped fracture with abduction of the arm and displacement of the fractured ends of the bone).

sue, the treatment which they require, and the sequelæ which follow. For the sake of convenience it is proper to make further subdivisions of each of these groups.

Fractures of the upper end of the humerus (Fig. 31) comprise those which involve that part of the bone which is situated above the insertion of the tendons of the pectoralis major and latissimus dorsi muscles. It will therefore include: (*a*) fractures of the head; (*b*) separation of the upper epiphysis; (*c*) fractures of the anatomical neck; and (*d*) fractures of the surgical neck.

In making an examination in a case of suspected fracture of the humerus it is necessary that both upper extremities and the upper part of the patient's chest should be fully exposed; and, if anæsthesia is not required, the patient should be seated on a stool, thus affording opportunity for comparing the two sides and noting the direction of the axes of the respective limbs. The surgeon should grasp the flexed elbow of the injured limb with one hand, while

with the other he steadies or palpates the shoulder and adjacent parts, and moves the arm carefully in different directions. In this way it will be possible for him to determine whether the head of the bone is in place. He will be able to determine whether the head of the bone is abnormal in any other respect —in shape, restricted movements, preternatural mobility, etc. It is desirable to note the condition of the circulation of the limb—whether, for example, there is normal pulsation in the axillary and radial arteries; he should also make, on both sides, accurate measurements of the distance from the apex of the acromion process to that of the external condyle, for purposes of comparison.

Simple fissures or *partial fractures of the head of the humerus*, without associated fracture of the tuberosity, are very rare, the usual fracture of the head being a separation of the greater tuberosity and a part of the articular surface from the lesser tuberosity and shaft. Such a fissure may be longitudinal or oblique.

The cause is a direct force acting from in front of the shoulder in a backward direction.

The symptoms are flattening and broadening of the shoulder, the acromion process being brought into prominence, though this latter sign is often obscured by swelling; the upper fragment may be displaced outward, and the lower inward, resting on the edge of the glenoid cavity; the arm is abducted and apparently shortened; crepitus is often elicited on manipulation. Ogston has pointed out that the biceps tendon sometimes gets between the fragments, and that in consequence more or less deformity results.

After reduction of the fracture by carrying backward the upper end of the bone and pressing the small fragments into place, one method of treating this condition is gently to apply the dressing for dislocation of the outer end of the clavicle over a shoulder cap of leather, felt, or perforated tin, with compresses properly adjusted. Immobilization of the joint, with the elbow a little advanced, is usually effective. Passive motion should be commenced during the fourth week, and resorted to every second day unless contraindicated.

Separation of the upper epiphysis (head of the bone) occurs very rarely and is produced by a direct force. Thus, for example, it has been produced by drawing the arm upward and outward, by a fall on the elbow at a moment when it was behind the axillary line, and, during parturition, by hooking the finger of the accoucheur into the axilla of the infant, or in bringing down the arm after the legs and body have been delivered. Since union of the head with the shaft takes place at about the age of twenty, epiphyseal separation could hardly happen after that time.

The following symptoms characterize a separation of the upper epiphysis (head) of the humerus: The lower fragment is drawn inward and forward by the pectoral muscles and can usually be felt beneath the coracoid process; the elbow projects backward and from the side; and if the head of the bone is

grasped between the thumb and finger, mobility will be felt on gently rotating the arm, and crepitus is produced.

The prognosis is usually favorable so far as bony union is concerned, but the growth of the limb in length will be affected if the patient is young.

As regards the treatment, the following measures may be recommended: A well-padded internal splint, with an axillary pad, should be applied to the inner surface of the arm, and this splint should extend down to the elbow; a shoulder cap, encircling one-half of the shoulder and arm, and extending well down the elbow, should be secured in position with adhesive plaster or a roller bandage; and, finally, the arm and forearm, while flexed at a right angle, should be fastened with a four-tailed bandage to the body. The dressing should be worn for four weeks; it should be removed occasionally and the parts bathed. Passive movements should be deferred until the end of four weeks.

Fracture of the anatomical neck is obscure and rare. The line of fracture follows the insertion of the capsule, sometimes within, but oftener both within and outside the capsule; and the terms intracapsular and extracapsular are applied to this fracture by some authors. The tuberosities are often involved. It is said to occur most frequently in advanced life. Indirect force, such as may be applied by a fall or a blow on the elbow or lower part of the arm when abducted, may cause it. The symptoms are mobility, pain, deformity (from swelling), impaired function, especially as regards abduction, and crepitus. The lower fragment is drawn inward and forward and can usually be felt on rotating the arm. Impaction sometimes occurs, and with it shortening of the limb. Erichsen says that in this fracture the head of the bone is not in line with the axis of the limb. The prognosis, according to Hamilton, is good so far as bony union is concerned, but more or less ankylosis is likely to result.

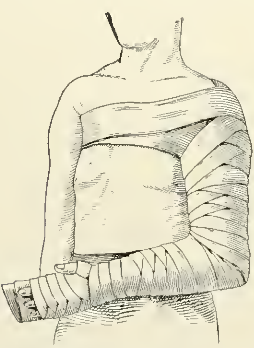


Fig. 32.—Shows Method of Applying Internal Angular Splint and Shoulder Cap in Fracture of the Surgical Neck of the Humerus.

The reduction of this fracture may require a general anæsthetic. Such, however, is not usually the case. A dressing similar to that recommended for separation of an epiphysis should be applied. Some surgeons treat this fracture by immobilization of the joint and traction by suspending the wrist in a sling and hanging a weight from the elbow for extension. The dressing should be changed frequently, and massage employed at the end of two weeks, care being taken not to move the joint for three or four weeks. Immobilizing may be necessary for six weeks, especially in impacted fractures.

Fractures of the Surgical Neck.—Fractures of the surgical neck involve the portion of the bone between the site of the epiphyseal junction and the inser-

tions of the tendons of the pectoralis and teres major muscles. They are quite frequent, especially in advanced life, and are usually transverse, sometimes oblique, and always complete; they may be impacted. (Fig. 32.)

They may be produced by either direct or indirect violence, and by muscular action. A frequent cause is a fall on the outstretched hand.

The symptoms are mobility, deformity (Fig. 33), shortening, flattening of the shoulder, crepitus, and pain running down into the fingers. The latter symptom is produced by pressure of the upper end of the lower fragment on the brachial plexus of nerves in the axilla. The flattening differs from that of a dislocation in that it is located farther below the acromion process. The head of the bone can be felt in the glenoid cavity, but it does not move when the arm is rotated. On rotating the arm do not mistake the movement of the upper end of the lower fragment for the head of the bone.

Fig. 33.—Fracture of the Surgical Neck of the Left Humerus. (Schreiber.)

The upper fragment is rotated and displaced outward, and the upper end of the lower fragment is pulled upward, inward, and forward. The upper fragment is moved and controlled by the supraspinatus, the infraspinatus, and the teres minor muscles. The lower fragment is moved upward by the deltoid and other arm muscles; inward and forward by the muscles inserted into the bicipital groove. The elbow, except in impacted fractures, lies backward and away from the side of the body.

The lower fragment is sometimes impacted in the upper, and thus many of the symptoms may be obscured.

An x-ray examination, however, will establish the diagnosis. Dugas' posture test will also be found helpful, especially as a means of differentiating a fracture from a dislocation of the shoulder. According to Dugas' sign, if the elbow and inner surface of the injured arm can be made to touch the side of the chest, while the hand of the injured arm rests on the opposite shoulder, the lesion is a fracture and not a dislocation.

The prognosis of fractures of the surgical neck is good, although sometimes non-union results.

The failure properly to immobilize the elbow joint and arm by confining

the forearm in a suitable splint often results in non-union in fracture at the surgical neck and in fractures of the shaft of the bone. Therefore I am in the habit of using, in this class of fractures, an internal angular splint (Fig. 32) with a shoulder cap (Figs. 34 and 35); a description of the angular splint will be found on page 131. Sometimes the shoulder cap is used alone, with the arm and forearm immobilized against the body.

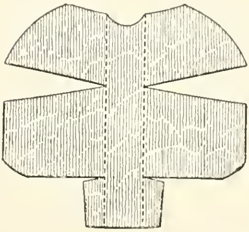


FIG. 34.—Diagram of a Simple Pattern suitable for a Shoulder Cap. (From Cheyne and Burghard.) The arrangement is shown applied in Fig. 35.

Reduction is accomplished by employing sufficient extension to bring the lower fragment into line with the upper one. At the same time manipulation of the arm may be required. The fragments must be held tightly while the splints are being applied. Permanent traction is sometimes needed for the purpose of preventing shortening with angular displacement. With the shoulder, the arm, and the forearm properly bandaged, the arm quite forcibly drawn obliquely downward and outward, and the forearm flexed at a right angle, a plaster-of-Paris dressing of such dimensions as to reach from above the shoulder down the arm, and beyond the flexed elbow to the wrist, entirely encasing the limb, should be applied. The limb is then permitted to fall to the side of the thorax, where it is retained by a bandage or sling. The impingement of the inner and upper edge of the splint on the axillary border is so adjusted by trimming or by padding as not to become a source of annoyance. If extension be needed it can be readily applied directly to the splint by a proper fastening of the shoulder-cap portion. In those rare cases in which there is a marked anterior projection of the lower end of the upper fragment, Da Costa advises the application of an anterior angular splint.

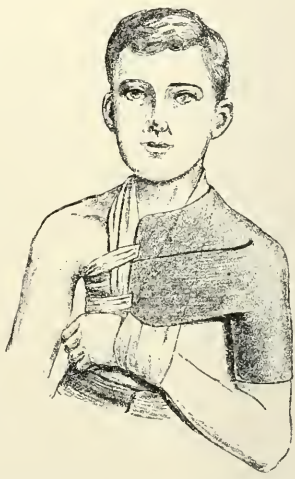


FIG. 35.—Shoulder Cap for Use in Fractures of the Humerus. (From Cheyne and Burghard.) The wrist sling is placed beneath the shoulder cap in order to obtain better fixation of the wrist. The splint is secured around the arm by a strap or bandage not shown in the figure.

Light massage should be used after the lapse of two weeks, and passive motion after four weeks. Splints should not be left off for six weeks, but they may be removed every few days and at once reapplied.

Haubold dwells on the difficulty of securing adequate fixation of the fragments in cases of this injury, and he describes how in one instance he obtained a successful result. Langenbeck's anterior incision was made, the deltoid separated from the pectoralis major, and the fracture exposed. The loose pieces of bone were removed. The fragments were brought into apposition with difficulty and by forcibly prying the lower fragment outward with the aid of a periosteal elevator. A small skin incision was made at the outer edge of the acromion process, and a four-inch steel nickel-plated nail driven through the head of the bone into the shaft, firmly fixing the fragments in place. About three-fourths of an inch of the nail, with its head, was permitted to protrude from the skin. At the end of a week a plaster-of-Paris dressing was applied, and four weeks later the nail was removed. Recovery of function was perfect. (*Medical Record*, New York, January 6th, 1906.)

This plan is not advised except in very unusual cases.

Fig. 36.—Oblique Fracture of the Middle Third of the Humerus. (Massachusetts General Hospital.)

Fractures of the Shaft of the Humerus.—Von Bruns claims that the shaft is broken in five per cent of all cases of fracture, making it, therefore, a fracture of very frequent occurrence. Complete fractures are usually oblique (Fig. 36), and the direction is most frequently from above downward, forward, and inward. Transverse fractures are rare, and so also are incomplete fractures, even in children. Occasionally a spiral or a torsion fracture is observed, the result of an accident connected with the handling of machinery. Compound and comminuted conditions are met with in this part of the bone.

The most common cause is direct violence, such as that inflicted by a fall, a blow, or the wheel of a moving vehicle. Occasionally indirect force, as that exerted by a fall on the elbow or on the extended hand, is the cause of the fracture. In certain cases it may result from muscular action, as in fisticuffs, in throwing a ball, in playing tenpins, etc. The so-called spontaneous fractures

occur from diseased bone, as when it is the seat of a syphilitic lesion, of an osteomyelitis, of a malignant tumor, etc.

The symptoms of fracture exhibited in these cases are local. The displacement varies according to the seat of fracture. When it is above the insertion of the deltoid, the upper fragment is drawn inward by the pectoralis major, the teres major, and the latissimus dorsi; and the lower fragment is drawn upward by the deltoid. When fracture occurs below the deltoid, the upper fragment is displaced upward and outward by the deltoid (Fig. 37), and the lower

Fig. 37.—Fracture of the Left Humerus. Skiagraph taken from the back. (Helferich.)

fragment upward and backward by the triceps and other arm muscles. Shortening to the extent of an inch and more sometimes occurs. Loss of function, numbness and tingling, and loss of power of the tissues supplied by the musculo-spiral nerve, which is sometimes injured as it lies in the musculo-spiral groove, are among the symptoms observed. Paralysis has been noticed, the patient being unable to extend the fingers or supinate the forearm. Interposition of this nerve between the fragments excites pain at the distribution of its branches.

The prognosis, on the whole, is good, but the humerus, when fractured, is more liable to non-union than is any other bone. Treves believes that this is

due to the interposition of muscular tissue between the fragments, and to the lack of fixation of the shoulder and elbow joints. Hamilton attributed it entirely to the movement induced by leverage of the forearm.

The proper mode of treatment is to reduce the fracture by extension, counter-extension, and manipulation. Apply an internal right-angled splint (Fig. 38) and a long external shoulder cap; pad both of these well, especially the right-angled splint in that part where the inner condyle is to rest. This splint should reach from the axillary space to the ends of the fingers, the forearm being flexed at a right angle with the arm. Apply the splint while traction is made on the arm from the elbow, and secure well the arm and forearm to the splint by two or three wide strips of adhesive plaster, placing the forearm in a position between pronation and supination. Fix the shoulder-cap splint, which should extend well down to the elbow, and then secure both in place with a spiral reversed bandage terminating as a spica of the shoulder. Finally, suspend the hand and forearm in a triangular sling from the neck. Some surgeons use, instead of the long shoulder cap, a straight splint or splints on the outside of the arm. The dressing should be worn five and a half or six weeks, and the forearm should remain suspended in a sling. The dressing should be changed every few days, but passive movements should not be made until the fourth or fifth week. Should it be impossible to maintain proper apposition of the ends of the fragments, they should be sutured. If the musculo-spiral nerve is lacerated or becomes involved in the callus, it will, in the former instance, require suturing, and, in the latter, liberation by chiseling (Fig. 15). In this connection, it is very important, for medico-legal reasons, for the surgeon to notice at the outset whether or not the musculo-spinal nerve is involved.

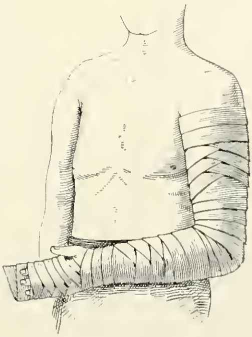


Fig. 38.—Shows Method of Applying Internal Angular Splint in Fracture of the Shaft of the Humerus.

A plaster-of-Paris splint is employed by many; but I must state that most of the ununited fractures of the shaft that I have observed were treated with plaster. I am therefore disposed to regard this mode of dressing these fractures as a causative factor in non-union. I believe that most plaster dressings become loose in a short time, and thus fail properly to immobilize the fracture, unless promptly cut up and kept tightened. Perhaps for this reason they may also fail to maintain proper extension, and consequently allow displacement of the fragments. Middeldorpf's triangle and Vulpius' aluminum splint are often applied in Germany for fractures of the shaft of this bone.

Gunshot fractures of the shaft as produced by modern firearms are almost

always comminuted. The point-blank shot wound of the modern small-calibre rifle produces comminution of the shaft. (*Vide* the article on "Gunshot Wounds" in Vol. II.) The management of such wounds calls for aseptic occlusion of the small wound in the skin and treatment of the fracture as if it were subcutaneous. Other compound fractures of this bone call for the same treatment as that which is employed in compound fractures generally. This subject will be fully considered in the section relating to fractures of the lower extremity.

Fractures of the Lower End of the Humerus.—These injuries are also called fractures of the elbow. They are not of a uniform character, but include the following varieties: Fractures just above the condyles; the same combined with an intracondyloid fracture penetrating into the joint (so-called T- or Y-fracture); separations of the epiphyses; intracapsular fractures of the articular portion of the humerus; and fractures of either or both the condyles—more frequently the inner. There are, of course, many complications of the above-named fractures. The following may be mentioned as among those which occur most frequently: fracture of the olecranon, of the upper end of the radius, and of the ulna; dislocations of both bones or either bone of the forearm; and injuries to the soft parts, especially the vessels and nerves.

Fractures of the lower end of the humerus are especially frequent in children, in whom they are caused either directly by a fall or a blow on the elbow, or indirectly by a fall on the hand.

In making a diagnosis, always compare the injured elbow with the one of the opposite side, noting the different bony prominences, first with the forearm flexed and then with it extended. In most cases, when it is possible to do so, the *x*-rays should be used in arriving at a diagnosis. It is well to use this valuable means later to determine if a perfect reduction has been secured. Da Costa suggests that in any case where the swelling is great, this should be treated before an examination is made and conclusions reached. The reduction of the swelling can be well effected by resting the arm semi-flexed on a pillow, and applying to it evaporating lotions or an ice bag for a day or two. In all cases ascertain the state of the radial pulse. Gerster sometimes applies an Esmarch's bandage from the hand to a point well above the seat of fracture, a procedure which will rapidly diminish the extra-articular swelling and soon permit a

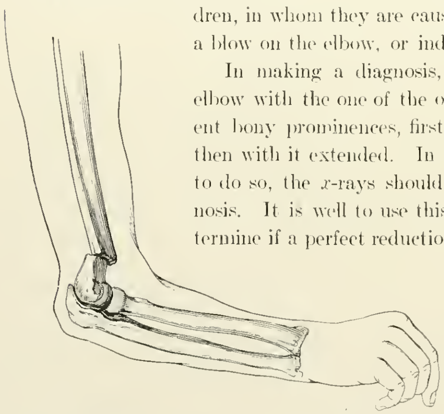


FIG. 39. Ununited Fracture of the Lower End of the Shaft of the Humerus, with Displacement of the Fractured Ends of the Bone. (Helferich.)

thorough examination. An anæsthetic is given and the bandage is quite firmly applied for ten or fifteen minutes; then it is removed and the injury diagnosticated and treated while the patient is yet unconscious.

In supracondyloid fracture (Fig. 39) just above the condyles the lower fragment is usually drawn upward and backward (extension fracture) by the triceps; and, owing to this circumstance, this fracture is frequently mistaken for a dislocation of the radius and ulna backward. The differential points are as follows: In a case of fracture, the forearm is flexed on the arm and is commonly in a state midway between pronation and supination; while in a dislocation there is often flexion of the forearm, but usually supination. Next, there is shortening of the humerus in fracture, and never in dislocation. Furthermore, the act of bringing the forearm into a straight line continuous with the arm will, in the case of a fracture, increase the prominence of the olecranon process, while, in the case of a dislocation, the prominence of this process will thereby be diminished.

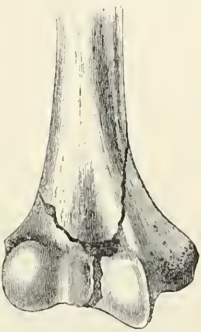


Fig. 40.—Y-shaped Fracture of the Condyles of the Humerus. (von Bruns.)

In most supracondyloid fractures the mobility is increased. The extra breadth in front of the elbow—a breadth which is diminished by full flexion—is of special diagnostic value in children. The tenderness of a localized point is of some importance in cases of incomplete fracture. Crepitus is easily disclosed in locating a false point of motion. The loss of function of the arm and the rotary displacement of the lower fragment, induced by leverage of the forearm, may readily occur, and in the planning of the treatment such measures should be adopted as will remedy such an occurrence.

Sometimes this form of fracture runs in the reverse direction, *i.e.*, backward and downward (flexion fracture), the lower fragment therefore appearing in front of the upper.

In this as in other forms of elbow fractures, the great swelling that quickly follows prevents satisfactory examination without the aid of an anæsthetic; in fact, it may be impossible to make a diagnosis in children even when an anæsthetic is employed.

When the supracondyloid fracture is combined with an intracondyloid (T- or Y-fracture [Fig. 40]) the fragments may remain together, but more frequently they are separated from one another. When they are separated, the elbow joint is strikingly broadened because of it and by the extravasation of blood, etc., and the condyles show abnormal mobility, accompanied by severe pain and crepitus on movement. The upper fragment sometimes forces itself between the lower ones and holds them apart. In other cases the entire articular end is shattered, giving rise to a comminuted fracture. The fracture is

sometimes combined with backward dislocation of the forearm, or the radius and ulna remain connected with the lower fragment and are pushed backward and upward. These fractures arise usually from great violence inflicted upon the olecranon, a violence which drives the condyles apart like a wedge. Such a degree of violence may be the result of a fall upon the elbow. In the latter case the fracture above the condyles may occur first, the upper fragment then forcing the condyles apart. The ulnar and median nerves are frequently more or less injured in these fractures, sometimes permanently.

In cases of separation of the epiphysis, the line of division runs at the lower border of the coronoid fossa in front and the olecranon fossa behind, from one epicondyle to the other. Such a separation may arise from violent rotation of the forearm, from hyperextension, and from abduction or adduction of the forearm in falling upon the hand. The epiphyseal separation follows the line of the cartilage, and this line is nearer the articulation than usually is that of a

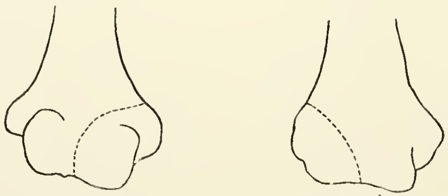


Fig. 41. Fracture of the Internal and External Condyles of the Humerus. (Diagrammatic, after Wilms.) *a*, Fracture of the internal condyle; *b*, fracture of the external condyle.

supracondyloid fracture. The position of the forearm is essentially the same as in simple transverse fracture above the condyles; the symptomatology is also the same.

Fracture of the lower articular surface of the humerus, or chipping-off of the articular surface, always results from direct violence, and is often accompanied by fracture of the olecranon process. Extensive comminution of the articular end, with long fissures, is observed especially in gunshot injuries. Complete intracapsular fracture at the lower extremity of the humerus is characterized by abnormal mobility below the epicondyles, upon fixation of the humerus and lateral movement of the forearm; often by simultaneous fracture of the olecranon; by abnormal passive mobility of the elbow joint while it is but slightly movable actively; by crepitus; and, finally, by swelling of the joint in consequence of intra-articular effusion of blood. The fracture is sometimes partly intracapsular and partly extracapsular. If it results from a direct force only, and the capitellum of the humerus is broken off by the head of the radius, crepitus can be determined by pronation and supination of the forearm with the fingers placed on the external condyle. There is often a distinct projection in front of the external epicondyle, and behind this is found the head of the radius.

Both condyles are frequently subject to fracture, the internal more often than the external, because it is larger, thinner, and more exposed to the violence of falls upon the elbow. The direction of the line of fracture separating the internal condyle from the rest of the bone is a fairly regular one; it begins above the base of the epicondyle and extends obliquely outward and downward

Fig. 42.—Gunstock Deformity in Condyloid Fracture. (Original.)

through the olecranon and the coronoid fossæ to the centre of the articular surface. (Fig. 40.) The action of the brachialis anticus and triceps muscles pulls the ulna with the fragment of the condyle upward and backward as far as the attachment of the radius will permit. This upward and backward displacement is increased by any pressure made upon the under surface of the olecranon or by lateral movements of the forearm toward the body. Some rotation of the

condyloid fragment with anterior displacement is caused when the forearm is extended. The effect of any upward displacement is to lessen the normal humero-ulnar angle and to convert it into one of the opposite direction, producing thereby the familiar "gunstock deformity" (Fig. 42).

The line of separation, in a fracture of the external condyle, usually enters the joint at a point in or near to the capitellum. The extensor and pronator muscles arising from it pull the fragment forward and downward, while the mobility of the condyle causes lateral deflection of the forearm at the elbow, producing again loss of the normal humero-ulnar angle and loss of the carrying function.

Condyloid fractures are detected by grasping the lower end of the humerus with the fingers of one hand, while with the other hand the bones of the extended forearm are gently rocked from side to side. Under this manipulation the broken-off condyle will be felt to move with the bones of the forearm, producing a lateral mobility at the elbow, which is not normally present. From the superficial situation of the condyles, crepitus is easily elicited; and crepitus and loss of function are the important signs upon which the diagnosis rests.

So far as the prognosis is concerned, the surgeon should bear in mind that a good result may usually be obtained by securing an accurate knowledge of the damage inflicted. The fact that a joint is involved does not necessarily bespeak a bad result. It is true, however, that compound and comminuted fractures of a joint may result in a stiff or deformed limb; but even this does not always follow. The thickening and contraction of periarticular structures following inflammation may produce permanent adhesions and thus cause limitation of motion. Practical coaptation and reduction of fragments are essential for successful treatment. While it is not always possible to obtain this result, yet it can be done in the majority of cases.

It is frequently necessary, in the treatment of this variety of fractures, to administer a general anæsthetic. In the application of dressings it should be remembered that in all persons the long axes of the forearm and arm are not the same (do not coincide), either in health or when in an injured state, when the limb is in the extended position. Normally, an obtuse angle is made (better marked in the female) by the forearm diverging outward; and the hand, when hanging by the side, is likewise carried outward. It is important, therefore, to maintain this angle, in order to give to the member unencumbered *carrying power*. I regard an anterior angular splint as superior to one that confines the forearm in an extended position. By placing the forearm in the latter position the humero-ulnar angle can be best kept under control; but, when it is thus placed, anterior rotation of the condyloid fragments is inevitable. Then, besides, the probability that there will be some impairment of the joint is increased, and, if ankylosis should result, the position of the limb will be the most objectionable. Besides these objections to the extended position,

there is the fact that the right-angled position is the most comfortable for the patient.

It is my experience that in condyloid fractures slight flexion answers as well in treatment as the right-angled position. It is held by some, however, that the forearm must be at a right angle with the arm if a complete reduction of the fracture is to be accomplished; it is also maintained—and wisely, as I believe—that this position gives the most general relaxation to the tissues in and about the joint.

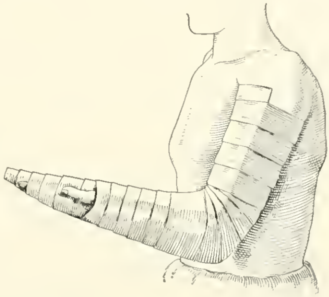


Fig. 43.—Shows Method of Applying Anterior Angular Splint in a Case of Fracture in or close to the Elbow Joint.

Great care must be exercised in reducing any of these fractures. In all except the supracondyloid fracture, reduction can be made by traction on the forearm, supinating, extending, and then flexing slowly to a right angle or even an acute angle. The supracondyloid fracture (extension fracture) should be reduced by making traction on the forearm (including the lower fragment) downward and forward, while at the same time the upper fragment is pushed backward. In fracture with reverse displacement (flexion fracture) the lower fragment should be pushed backward while extension and flexion are being made.

The anterior right-angled or acute-angled splint, made of light wood (pine), should be well padded on its outer surface, especially over its convexity where it will exert pressure in front of the joint, and should extend from in front of the shoulder, past the wrist, to the ends of the fingers. In applying this splint it will be well to fasten the upper end to the arm by a broad strip of adhesive plaster applied in front of the arm, and then to make extension of the forearm before it and the hand (placed in the supine position) are secured in the same manner to the lower end of the splint. The next step is to apply a bandage in such a manner as to make a figure-of-8 over the elbow (Fig. 43). A piece of leather or pasteboard can, if desired, be moulded to the posterior surface of the arm and forearm and then be fixed with the bandage at the same time that the angular splint is secured. A Stromeyer splint, which admits of motion, by means of a screw, without removing the dressing, is sometimes employed after the second or third week. Some surgeons use a posterior right-angled trough instead of the anterior angular splint, and claim that it is more easily kept in position. A very popular method is to extend the limb and then to apply a plaster-of-Paris dressing which is to remain undisturbed for a period of three weeks; after which the anterior angular splint is to be worn during the remaining time of

the treatment. If complete ankylosis occurs with the limb in the extended position, the arm is nearly useless without resection.

Jones, of Liverpool, England, advocates placing the arm in the position of acute flexion, without the aid of splints, as the best method of treating all condyloid fractures in children. He thinks that splints and bandages are responsible for ankylosis of the elbow joint, and believes that the position of acute flexion forces the fragments into place and holds them after they have thus been reduced. The position of acute flexion is utilized in the following manner: A bandage carried through a rubber tube is passed around the neck and fastened to the wrist in such a manner as to make the ball of the thumb rest on the base of the neck. In other respects the limb is dressed and cared for in accordance with indications. Frazier has modified Jones' dressing in the manner shown in Fig. 44. In very young children I would prefer to use the Jones dressing as modified by Frazier, rather than a right-angled anterior splint.

Fig. 44.—Shows Frazier's Modification of Jones' Dressing for Injuries of the Elbow Joint.

In any fracture of the elbow passive motion should not be made before the third week, and in complicated fractures not before the fourth week of treatment, and then only provided it can be done without particular pain. Earlier attempts are apt to disturb the fragments and increase the formation of callus. At the end of five or six weeks all dressings may be discontinued. The slight stiffness generally present will gradually disappear in the course of time. If it does not, manipulation under anæsthesia, to break up the adhesions, may be required.

The Bones of the Forearm.

Fractures of the bones of the forearm are divided into special fractures of the ends of the ulna and radius; fractures of the shaft of each bone; and fractures involving both bones.

Special Fractures of the Ends of the Ulna and the Radius.—Of this first group, the most frequent is fracture of the olecranon; next in frequency is fracture of the head and neck of the radius; and the least frequent of all is fracture of the coronoid process of the ulna. One or more of these fractures are sometimes complicated with fracture of the lower end of the humerus, or with dislocation at the elbow.

Fracture of the Olecranon Process.—The olecranon process, from its exposed position, is comparatively often fractured. The causes are: direct violence; falls on the elbow; muscular contraction of the triceps, as in throwing; and also hyperextension, as in falling upon the hand. In these ways the olecranon is forced against the trochlear surface and its tip is broken off. The olecranon is broken in from one to two per cent of all cases of fracture, and it constitutes about one-third of the fractures of the ulna.

Symptoms.—The fragment is more or less drawn up and in proportion to the extent to which its fibrous coverings have been stretched or torn. The displacement is commonly due to the contraction of the triceps (Fig. 45), and usually shows distinct bulging above, especially when complete detachment of

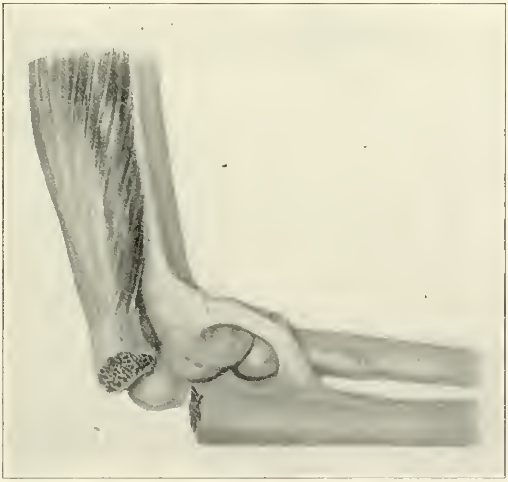


Fig. 45.—Dissection of an Artifically Produced Fracture of the Olecranon. The drawing shows how the elbow joint is opened in such an injury, and how the upper fragment tends to be drawn upward by the triceps muscle. (Helferich.)

the entire process has taken place; in which event there is apt to be a dislocation of the ulna forward. The space between the fragments of the bone may be hardly appreciable or may measure from half an inch to two inches in length. Occasionally, owing to the fact that the periosteum has escaped being torn or that the expansion of the triceps tendon has resisted enough to hold the fragments together, there may be no apparent separation, or one that can be detected only with difficulty. In the latter case it may be possible, by slightly rocking the upper part, to elicit a false point of motion and crepitus. When there is a marked degree of separation the false point of motion is self-evident and therefore the search for crepitus can be dispensed with. The arm is par-

tially flexed, active extension even in the horizontal position is impossible, and there is early swelling of the joint.

Treatment.—An anterior splint so padded as to make the limb comfortable, extending from the level of the axillary margin to the palm of the hand, should be applied. Before the splint is applied the upper fragment should be pulled down in contact with the lower and held by a broad strip of adhesive plaster. It may be well to keep the patient in bed the first week. Ankylosis and too great length of the fibrous union are to be avoided if possible. In the latter, care must be taken in securing apposition of the fragments; in the former, passive motion, beginning at the end of the third week, should be kept up every second or third day during the five or six weeks required for the establishment of firm union. In cases of non-union, and in compound and comminuted fractures, it may be necessary to wire together the fragments. Mayo Robson, by means of a stout needle, passed one end of the wire through the triceps, as close to the bone as possible, and the other through the fibrous tissue over the distal fragment, and thus secured good union. If the fibrous connection is too long it may be excised and the bony ends freshened and sutured together. In cases of comminuted fracture, useless fragments may be removed, sharp edges rounded off, and the remainder sutured. If ankylosis cannot be prevented, owing to the great extent of the injury, the straight position must be abandoned and the flexed taken, as it leaves the arm in the most useful position.

Fig. 46.—Specimen of Fractured Olecranon, and Diagram Showing how the Fractured Ends become United by Fibrous Tissue. (Helferich.)

Murphy, of Chicago, advocates treating fractures of the olecranon by subcutaneous exarticular wiring.

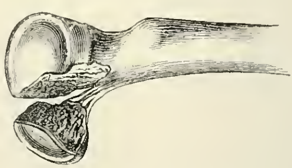


Fig. 47.—Fracture of the Capitellum of the Radius. (von Bruns.)

Murphy makes a longitudinal incision one-third of an inch long on the external aspect of the ulna, one-half inch from its articular surface, down to the bone. He then makes a smaller incision on the corresponding inner side and perforates the base of the olecranon transversely with an eyelet drill. He threads the drill with a fine aluminum-bronze wire and draws it through the canal. He carries the wire upward under the skin on the inner surface

of the elbow and then draws it out through another small incision, one-sixteenth of an inch long, made at the level of the apex of the olecranon. He reinserts the wire and directs it transversely from inward outward, passing it through the tendon of the triceps above the olecranon, and then draws it out to a corresponding outward point through a very small incision similar to that made on the inner side. Again he reinserts the wire and pushes it downward under the skin, bringing it out finally through the initial external incision. The circle once completed, he exerts traction on the wire until he is sure that the two fragments are in perfect coaptation. The operation completed he dresses the wound.

Prognosis.—The prognosis is good, but union is nearly always fibrous (Fig. 46), and, if it is not of too great length, the function will be good. Care should be taken to prevent undue lengthening of the fibrous union, or the power of extension of the limb may be enfeebled. Some stiffness of the joint may fol-

Fig. 48.—Fracture of the Coronoid Process at its Base, Showing Displacement due to Action of Brachialis Anticus. (Helferich.)

low and persist for an indefinite length of time. Ankylosis is also a possible result. Faulty union may be caused by the interposition of capsule or tendinous tissue.

Fractures of the Head and Neck of the Radius.—The head and neck of the radius are fractured very rarely. The so-called chisel fracture of a segment of the head is obliquely detached, but is usually held by periosteum at its lower end or at the neck of the bone, and is thus hard to differentiate from a fracture of the neck. These fractures are sometimes incomplete or mere fissures, and accompanied by dislocation.

The causes are direct and indirect violence.

Symptoms.—Palpation may reveal a small portion of the head of the radius broken off (Fig. 47). The arm is pronated and the power of pronation and supination is in abeyance. The lower fragment may be pulled upward and forward by the biceps, and, when this happens, the broken end of the bone will be felt in front of the joint. Crepitus may be elicited on rotating the forearm.

Treatment.—To prevent displacement by contraction of the biceps, it will be found necessary to fix the fractured limb in a semi-flexed position. The use of

the anterior angular splint, or placing the limb in Jones' position (page 138), will suffice. If only a small fragment is broken off, it may be removed.

Fracture of the Coronoid Process of the Ulna.—This variety of fracture (Fig. 48) is very rare, and is associated with a backward dislocation of the ulna. If it is found that the dislocation can be easily reduced, examine carefully with x-rays for the presence of this form of fracture. It occurs at a varying distance from the top of the process, and it may be associated with other fractures at the elbow.

Causes.—An indirect force that has produced a backward dislocation of the ulna, or of the ulna and radius, may also have broken off, either transversely

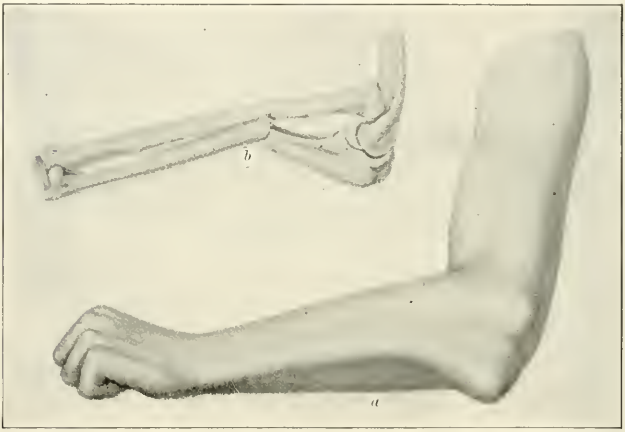


Fig. 49.—Fracture of the Ulna, with Displacement of the Head of the Radius. *a*, Drawing made from a photograph of a young subject in whom a fracture like this had occurred. The angular bend of the ulna and the projection of the head of the radius are both shown; *b*, a dissection similar to that shown in Fig. 39. In this case, however, the head of the radius is displaced more directly upward. (Helferich.)

or somewhat obliquely, a piece, about one-fourth of an inch or more in length, of the tip of the coronoid process.

Symptoms.—A dislocation backward of the ulna, or of both bones, may as a rule be easily reduced by flexion and extension applied to the forearm, but as soon as force is discontinued the dislocation may return unless the forearm be flexed, at which time crepitus may be noticed. The fragment may be pulled upward by fibres of the brachialis anticus muscle, and the patient may not be able to flex the forearm completely. The broken piece may be felt in front of the ulna.

Treatment.—Treatment in the flexed position of the forearm is proper. Ankylosis may follow, and should be guarded against.

Fractures of the Shaft of the Ulna and the Radius.—*Fracture of the Shaft*

of the Ulna.—This fracture is most frequent in the lower third of the ulna, and is usually due to direct force, as in an effort to ward off a blow. Rarely indeed is indirect force the cause of fracture of this bone alone, for an indirect force sufficient to fracture the ulna is quite certain also to break the radius (Figs. 49 and 50).

Symptoms.—The long axis of the hand may be out of line with the axis of the forearm; there is a depression at the site of fracture; deformity due to the lower fragment being displaced toward the interosseous space may be noted; and, besides which, a false point of motion and crepitus may be observed.

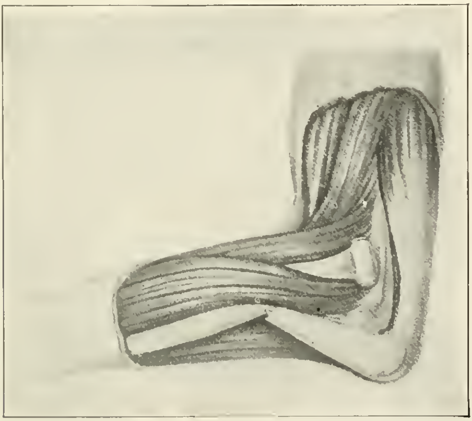


Fig. 50.—Fracture of the Ulna in the Upper Third, with Dislocation of the Radius. The left elbow seen from the outer side. There is marked displacement at the site of fracture in the olecranon, and the head of the radius rests above the external epicondyle. (Helferich.)

Treatment.—The treatment is the same as for fractures of both bones of the forearm, and will be fully considered later (page 147).

Fracture of the Shaft of the Radius.—Fracture of the shaft of the radius results from both a direct and an indirect violence, and happens more frequently than fracture of the shaft of the ulna. The weakest point of the radius is at the middle third. The character of the deformity is modified by the location of the fracture. Thus, for example, if it occurs above the insertion of the pronator radii teres muscle, the upper fragment will be flexed upward by the biceps and supinated by the supinator brevis (Fig. 51); and the lower fragment will be pronated by the pronator quadratus and pronator radii teres. If the fracture occurs below the insertion of the last-named muscle, the upper fragment, controlled by the biceps, supinator brevis, and pronator radii teres, will likely be found midway between pronation and supination; while the

lower fragment, which is subject to control of the supinator longus and pronator quadratus, may be in about the same position.

Symptoms.—The long axis of the hand is deflected to the radial side of the forearm (Fig. 53); there is a depression at the point of fracture, and there is also some deformity modified by the location of the fracture; the head of the radius is not rotated by rotation of the forearm; and, finally, all the other signs that characterize fractures in general are present.

Treatment.—If the fracture is above the insertion of the pronator radii teres, reduce it by flexing and supinating the forearm, to cause the lower fragment to correspond with the upper, and by applying an anterior

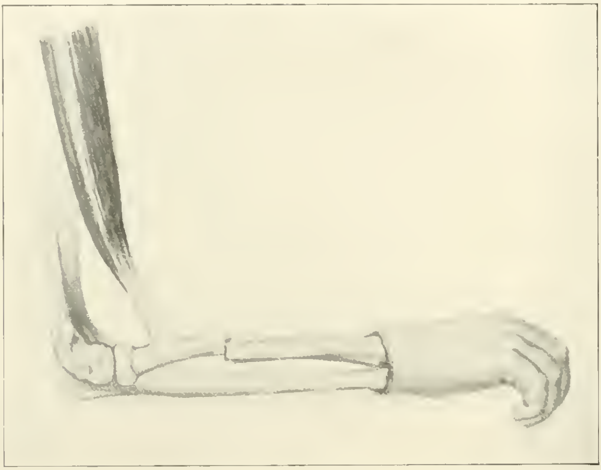


Fig. 51.—Fracture (experimental) of the Radius alone. The drawing shows how the upper fragment is pulled upward by the biceps, while the lower fragment remains in full pronation when the hand is turned over, palm downward. Union, under these conditions, would be attended with complete loss of the power of rotation. (Helferich.)

angular splint, as in fracture of the lower end of the humerus. The splint should be worn for about four weeks, without passive motion being made. If the fracture occurs below the insertion of the pronator radii teres the treatment required is the same as that for fracture of both bones of the forearm. (See the next section.)

Simultaneous Fracture of the Shafts of Both Bones of the Forearm.—Fracture of the shafts of both bones of the forearm is of frequent occurrence, but not as frequent as fracture of either bone separately.

The line of fracture is often transverse, sometimes oblique, and less often spiral. If the force is direct, the bones usually break at the same level. In

92 cases Oberst found the break to be at the same level in 50; in 31 he found it higher in the radius, and in 11 higher in the ulna. Fractures of both bones are relatively frequent in children, the variety usually observed being the typical "green-stick fracture." Comminuted fractures occur in many forms, and coaptation of the fragments is difficult. Compound injuries of the

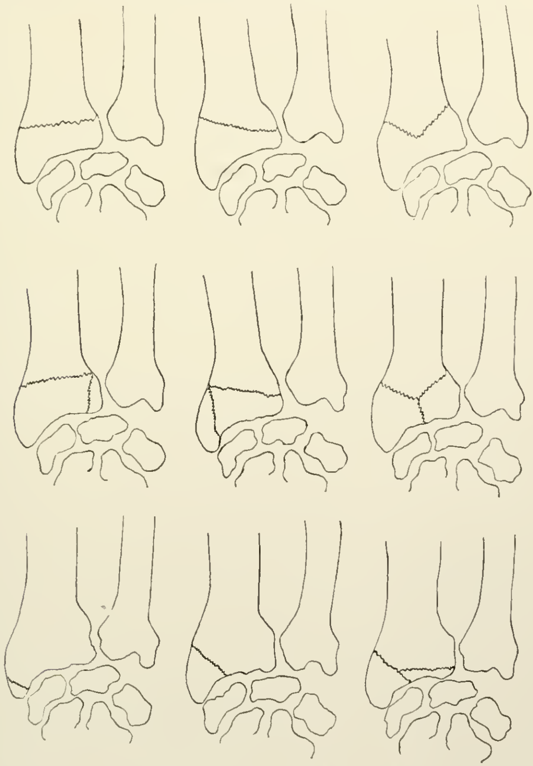


FIG. 52.—Different Lines of Separation in Cases of Fracture of the Lower End of the Radius (Diagrammatic, after Kahleyss and Oberst.)

radius and ulna are of frequent occurrence. All the variations in fracture to which long bones are liable may be observed in fractures of the bones of the forearm; even those due to muscular action alone have been reported.

Causes.—In most cases the fracture is produced by a direct force, such as a blow; less frequently by an indirect force; and, rarely, by muscular contraction. A direct force causes crushing or comminution in some cases, and in others a transverse or oblique fracture at the same level in both bones (Fig. 56).

Symptoms.—There will be displacement of the fragments, and the direction of this displacement will depend on the direction in which the force was exerted, on the weight of the arm, and on the part played by muscular action. Among the other symptoms may be mentioned: Pain; abnormal mobility; crepitus;

Fig. 53.—Skiagraph of a Fracture of Both Bones of the Forearm in a Young Subject. (Helferich.)

angularity; shortening; projection of the lower fragment on the flexor or dorsal surface; narrowing of the breadth of the forearm at the point of fracture; the forearm and hand usually pronated; failure of the head of the radius to rotate

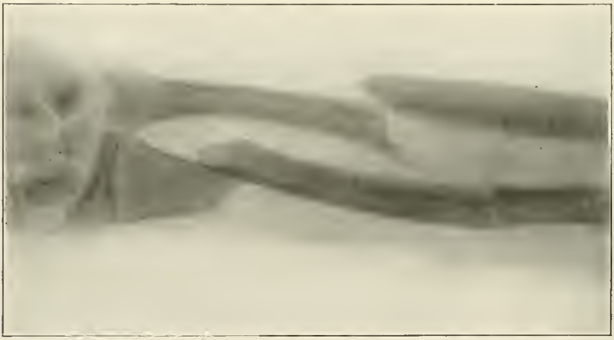


Fig. 54.—Compound Fracture of Both Bones of the Forearm. (Massachusetts General Hospital.)

in rotatory movements of the wrist; "hammock-curve" displacement; and impairment of voluntary pronation and supination.

Treatment.—A full understanding of the different displacements is very necessary for the adoption of a correct plan of treatment. A simple transverse fracture of both bones on the same level, without much displacement, can be

readily reduced by extension and manipulation, and firm union will be secured in the course of about four weeks by means of almost any form of proper immobilization.

The prevention of encroachments of the fragments and of reparative material on the interosseous space is a matter of importance, since the functions of pronation and supination are hindered thereby in direct proportion to the degree of encroachment, and even may be entirely lost because of an excess of it.

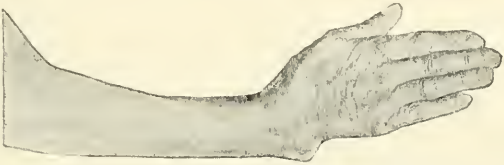


Fig. 55.—Typical Fracture of the Lower End of the Radius, with Marked Displacement of the Hand toward the Radial Side of the Arm. (Schreiber.)

The prevention of this infliction, so far as is possible, comprehends the taking of measures to keep apart the bony fragments during the process of repair. This may be attempted by using an anterior splint with an elevated ridge along its central portion, the presumptive effect of which is to keep the broken ends of the radius and ulna pressed apart. There are those, however, who regard the influence exercised in this respect by pressure upon the deep muscles of both surfaces of the forearm by the means of ordinary splints as being equivalent to, if not better for the purposes of separation than, specially fashioned splints like the above. The splints employed should be a little wider than the

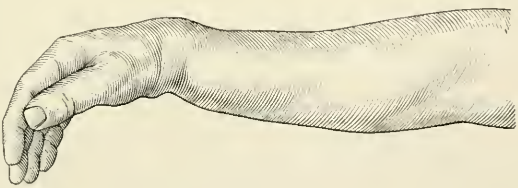


Fig. 56.—Colles' Fracture ("Silver-Fork") of the Lower End of the Radius (Schreiber's Case).

forearm; and the forearm should be placed at a right angle to the arm, midway between pronation and supination. After the limb has been dressed it should be held in this position by means of a sling suspended from the neck. In this manner lateral pressure of the encircling bandage on the forearm is prevented by the splints being a little wider, and the position midway between pronation and supination places the bones farthest apart. The plaster-of-Paris dressing for a fracture of both bones of the forearm is very

liable, unless carefully adjusted and moulded, to press upon the sides of the forearm, tending to cause the fragments to encroach upon the interosseous space. Furthermore, it crowds the bones toward each other and thus favors crippling of the member. A common plan of treatment is, first, to reduce the fracture, and then to apply two properly padded straight wooden splints: a dorsal, long enough to reach from the elbow joint to beyond the ends of the fingers, and a palmar, extending from the upper third of the forearm to the wrist; in which position they should be secured by adhesive strips of plaster and a suitable bandage. As already stated, the splints must be a little wider than the forearm, and the splint that is to be applied to the flexor side may have an elevated ridge along its central part. As a substitute for this ridge, a compress made of gauze or muslin, about the diameter of a lead pencil or a little larger, can be provided. The forearm should be swung from the neck in a triangular sling.

The splints should be worn for four weeks, and passive motion should be begun in the third week. Von Bergmann, in speaking of the treatment of fractures of both bones of the forearm, advocates that the splint should extend from above the elbow to below the wrist, to prevent rotation.

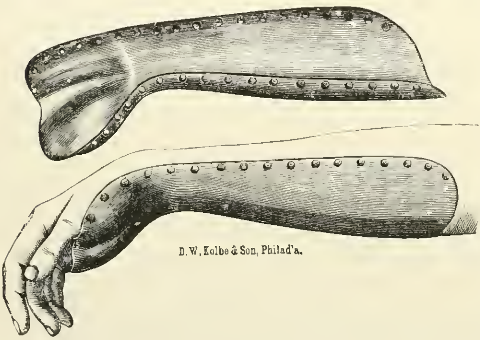


FIG. 57.—Levis' Splint for Fracture of the Lower End of the Radius.

The bones of the forearm are sometimes fractured near the wrist, the bones here being so lightly covered with soft tissues. The abnormal mobility and crepitus suffice for diagnosis. The treatment is the same as for Colles' fracture.

In rare instances the styloid process of either the ulna or the radius is fractured. The diagnosis is made by manipulation and palpation. The proper treatment is immobilization by means of a palmar or a dorsal splint; some surgeons, however, prefer to deflect the hand toward the side on which the styloid is broken. A strip of adhesive plaster may be applied around the limb at the seat of fracture before the splint is put in position. Passive motion should be commenced at the end of the third week, and the dressing may be dispensed with at the end of the fourth week.

Volkmann's contracture is not an infrequent sequel of a severe injury, usually in the region of the elbow joint, and generally in young children. It happens, however, sufficiently often to cause embarrassment. A well-known English

authority describes it as "a contraction of the fingers and sometimes of the wrist, which comes on rapidly with loss of power in the forearm muscles. The deformity is due to changes in the flexor muscles without injury to the peripheral nerves, being caused in many cases by tight bandaging and the pressure of splints."

Massage and electricity are used, but they accomplish little benefit.

Rowland, surgeon to East London Hospital, reports the treatment of a case by excising portions of the radius and ulna.

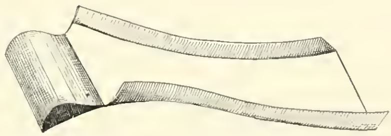


Fig. 58.—The Metal Framework of Bond's Splint for Fracture of the Lower End of the Radius.

Fracture of the Lower End of the Radius—Colles' Fracture.—This variety of fracture occurs at the lower end of the radius, at a point within an inch and a half above the wrist. This fracture is the most frequent of all fractures except those of the clavicle. It is usually transverse and may be more or less comminuted. This injury is very common and is met with at all ages; in the young it is usually found along the epiphyseal line. Prior to the publications of Pouteau (1873) and Colles (1814) this fracture was regarded as a backward dislocation at the wrist. Colles described it as occurring at a point an inch and a half above the carpal end of the radius, but we know now that it may occur at any intervening point. (Fig. 52.)

Causes.—The most frequent cause is a fall upon the extended hand, as a result of which the carpus is forcibly pushed upward toward the posterior surface of the wrist, thus causing the lower fragment to be displaced upward and backward. Some believe that the force is received on the ball of the thumb, in the fall on the hand, and that the fracture is due to a cross strain on the bone when the hand is forcibly carried backward. The amount of force varies greatly, depending upon the weight of the body and upon the distance and velocity of the fall. It is reported that the fracture may occur from other causes. A slight fall on the floor or the ground is sufficient, in the case of an old person, to cause a Colles' fracture, the hand, as in other instances, being involuntarily extended and receiving the force of the fall.

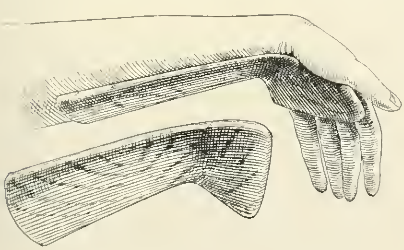


Fig. 59.—Bond's Splint Padded and Applied.

Symptoms.—The characteristic deformity to which the name of "silver-

fork" (Fig. 56) was given by Liston is sometimes so marked as to permit of a diagnosis at a glance. The hand is deflected to the radial side and pronated, the styloid process of the ulna is prominent, and the lower fragment rides on the posterior surface of the upper, causing a dorsal elevation. Pronation and supination may be lost. Crepitus is not needed to establish the diagnosis in the great majority of cases. Impaction sometimes occurs, the upper fragment being driven into the lower, and the latter at times being split into several pieces. Sometimes the impaction is quite firm, the lower end of the upper fragment of the radius being felt on the flexor side of the wrist. Broadening at the wrist and lateral projection of the ulna, termed "bayonet deformity," are symptoms usually to be noticed (Fig. 55). Pain may be slight if impaction is present. The injuries sustained by the soft parts are extensive. The ligaments are strained and lacerated, the tendons and sheaths contused, and the synovial sacs filled with blood. It is stated "that dissection of the parts shows that the periosteal and aponeurotic structures, stripped up from the back of the proximal radial fragment, instead of being torn across, constitute soon a strong band, which is made tense by the forward flexion of the wrist, and while thus tense tends to hold the fragments in impaction and hinders their separation by traction and ready replacement by pressure. If union occurs without complete replacement of the lower fragment, the space which is left between this detached periosteal layer and the posterior surface of the bone becomes filled with plastic material, which, by subsequent ossification, so encases this portion of the radius in new bone that, upon subsequent section, it presents the appearance of deep penetration of the lower by the upper fragment" ("International Text-book of Surgery"). Occasionally anterior displacement of the lower fragment is observed in this fracture. Pilcher has demonstrated the fact that when, in this fracture, a portion of the dorsal periosteum escapes being torn, the untorn portion acts as a binding force to hold the fragments in a state of deformity. Hamilton claimed that the action of the flexor carpi radialis and the pronator quadratus, and the entanglement of the styloid process of the ulna in the annular ligament, are also important causes in the production of the "silver-fork" deformity.

Treatment.—Colles' fracture has been the cause of more suits for malpractice than perhaps all other fractures combined. We therefore should strive to minimize deformity, which is the rule.

It is of great importance thoroughly to reduce this fracture. Levis suggests the following: First, make hyperextension, to unlock the fragments and relax the dorsal periosteum; secondly, make longitudinal traction to separate the fragments; and, lastly, make forced flexion to get them into position. Levis' splint (Fig. 57) is a commendable correcting agent. It maintains reduction and controls in some measure the extensor muscles. Bond's splint (Figs. 58 and 59) places the hand in a natural position of rest, with semi-extension of the wrist

and deviation of the hand to the ulnar side. Roberts uses a straight dorsal splint with satisfactory results. The late Dr. Moore used a cylindrical compress over the ulna and kept it in place by means of adhesive plaster. He then placed the forearm in a sling and allowed the hand to hang down over the edge of the sling. Koenig recommends the employment of Roser's posterior splint, with a pad on the back of the hand, and the hand itself allowed to hang down in flexion. Schede's anterior strip, as it is called, is a device that is popular with many German surgeons. Helferich recommends Storp's suspension cuff (Fig. 60). It is applied as follows: "After reduction is accomplished, the hand is brought into extreme adduction and flexion; a strip of adhesive plaster about four inches wide is wound several times around the lower end of the forearm down to the styloid process; a second strip forms a loop over it on the posterior surface, to which a sling is fastened." This strip or loop is attached over the middle of the radius on its dorsal surface, so that when the hand is suspended from the neck by the sling it will be in ulna-volar flexion.

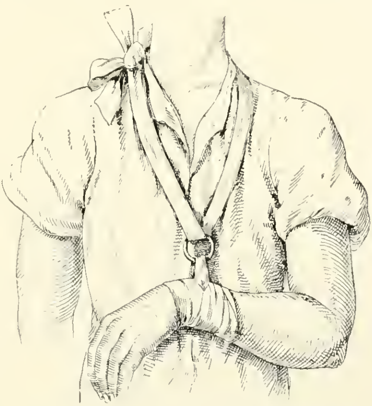


Fig. 60.—Colles' Fracture Treated Without Splints, by Storp's Suspension Cuff. (Helferich.)

After an extended trial I have come to look with favor upon the Gordon pistol-shaped splint, or Nélaton's position of the injured member. This splint is not the old full-angled one, but a splint that accomplishes sufficient ulnar deflection of the hand and fingers. It is placed on the dorsal surface of the forearm and hand, and extends from the upper part of the forearm down past the fingers. A second short anterior splint extends from the wrist upward to a point beyond the junction of the middle with the upper third of the forearm. These splints are to be fitted by means of suitable compresses, viz., a large compress posteriorly over the lower fragment, and a small anterior compress over the lower end of the upper fragment. The dressings should be removed and reapplied every few days. In favorable cases the anterior splint may be dispensed with at the end of three weeks. In old persons it is well, at the end of four weeks, to apply a straight dorsal splint for two weeks longer. Massage and passive motion should, as a rule, be commenced at the end of the second or the third week.

If a stiff joint and limited use of the tendons remain after the dressings have been removed, the application of sorbefacient ointments, tincture of iodine, electricity, and hot-water douches and massage will be beneficial. Some-

times it is necessary, in overcoming adhesions, to employ a general anæsthetic. If, however, the patients themselves will carry out faithfully the proper directions regarding manipulation of the limb, and especially the use of hot-water douching and packing, a useful member may be secured. The free use of hot water and squeezing of a soft rubber bulb (by the patient) after the splints are removed should be insisted upon by the surgeon.

Fractures of the Lower End of the Radius, Involving the Wrist Joint.—A fracture of this nature has been designated as *Barton's fracture*. Of this fracture Stimson says "that it should not be classed as a variety of fracture, but as a complication of a dislocation of the wrist backward." Yet in the same paragraph he says that he has seen only two cases, in which "a narrow fragment of the posterior articular border had been broken off, remained attached to the capsule, and was displaced backward with the bones of the wrist." Authorities are not agreed as to the line of this fracture. However, the majority agree that it is an oblique fracture of the lower end of the radius and that the line of fracture extends into the joint. Some attempt to confine it entirely to the posterior lip of the radius. The causes are similar to those which produce a Colles' fracture, for which it may be mistaken. The evidences, however, are, for obvious reasons, much less pronounced.

The treatment, after reduction, is to immobilize the wrist joint by two well-padded splints which should extend well up the forearm; it is also important to observe the general principles that govern the treatment of fractures in and about a joint.

Separation of the lower epiphysis of the radius is reported as having occurred in rare instances in children, as the result of falls upon the palmar surface of the hand. The deformity is quite similar to that observed in Colles' fracture, but the hand is not inclined to the radial side. The treatment should be the same as for Barton's fracture.

Fractures of the Carpal Bones.

Fractures of the carpal bones are very rare. They occur as a result of direct injury, and are almost always compound, sometimes comminuted and complicated. Severe crushes, injuries by machinery, and gunshot wounds are usually the cause, and the injury of the soft parts is, as a rule, the most important consideration.

Usually there is not decided displacement. A fragment, however, may be entirely torn away or pushed out of position. A false point of motion is apt to be confounded with the natural mobility of the bones, but crepitus may be elicited. The superficial nature of the bones renders the diagnosis comparatively easy. However, care must be taken to differentiate a fracture in this locality from a severe contusion or sprain.

The scaphoid is the most liable to be fractured, but, on account of the absence of the ordinary signs of fracture, this lesion is apt to be overlooked The presence of pain, tenderness, and swelling over the region of the bone, with the history of injury, should suggest the fracture.

Treatment.—Reduce the fracture by extension and manipulation. Secure immobilization by the application of a well-padded palmar splint, which should extend from the ends of the fingers to beyond the middle of the forearm. In addition, a compress may be placed immediately over the fracture. Finally, the hand should be suspended in a sling. In a simple fracture the splint should be worn about four weeks, and passive motion should be commenced at the end of the second week.

Fractures of the Metacarpal Bones.

The metacarpal bones are fractured by direct and by indirect violence. The first metacarpal bone is most frequently and the third least often broken. The most common indirect cause is violence acting on the distal end of the bone in the long axis, as when a blow is struck with the fist. A blow on the palmar or dorsal surface and crushing injuries are the frequent direct causes.

The symptoms are abnormal mobility, crepitus, pain, inability to use the fingers, and deformity due to displacement of the distal fragment. This last symptom may be slight or entirely wanting.

Treatment.—Reduction having been accomplished by extension applied to the finger corresponding to the fractured bone, immobilize the part by splints in a suitable manner for about three weeks. At the end of the second week it is advisable to begin passive motion. If the third or fourth metacarpal bone is broken, it may be sufficient to apply a simple padded palmar splint, with a roll of gauze or rubber tubing on either side of the bone, and, over all, strips of adhesive plaster and a bandage. In fracture of the first, second, and fifth metacarpal bones especial care should be taken to prevent deformity. The comparative importance of the first, as indicated by its varied movements and bountiful musculature, suggests the need of caution and vigilance in the treatment.

Fracture of the Stave of the Thumb, or "Bennett's Fracture."—In his address before the Section on Surgery of the British Medical Association, 1885, Edward H. Bennett, professor of surgery in Trinity College, Dublin, drew attention to a fracture at the base of the first metacarpal bone, the first note in regard to which he had published in 1881. Dr. Raymond Russ, of San Francisco, Cal., in the *Journal of the American Medical Association*, June 16th, 1906, reports eight cases of this fracture, observed during a single year. In this report he expresses the belief that this is one of the commonest as well as most important of the fractures of the metacarpal bones. In the surgical dispensary of the

University of California, in which most of these cases were observed, an inspection of the official records showed that during that particular year there was a decided falling off in the number of diagnoses of "thumb sprains" and "metacarpo-trapezial subluxations," and Russ draws from this the inference that in previous years a number of actual fractures of this first metacarpal bone must have been overlooked. It is certainly at times very difficult, without the aid of the x-rays, to establish the diagnosis of fracture, and Russ believes that to this fact must be attributed the frequent failures to ascertain its existence and the consequent impression among surgeons that it is rare.

Fig. 61.—Metal Splint for Fractures of the Phalanges. (From Cheyne and Burghard.) The trough receives the finger, while the flattened rounded portion goes into the palm of the hand.

The line of fracture, according to Bennett, runs obliquely across the palmar half of the articular (metacarpo-trapezial) surface of the bone, and the shaft slips upward and backward past this detached fragment, simulating a backward dislocation of the thumb. The force which causes such a fracture must, as Russ believes, be considerable, and it is usually applied to the distal end of the metacarpal bone, although in one of his cases the injury was inflicted on the palmar surface.

Dr. Russ recommends that the thumb be put up in a strong position of abduction and held in this position by an internal rectangular cardboard splint.

Fractures of the Phalanges.

Fractures of the phalanges are commonly due to direct violence, and they are often compound, or accompanied by lacerations and bruises of the soft parts. Indirect force, as by a fall or a blow on the ends of the fingers, or by the finger being immovably held against opposition, may cause fracture.

The proximal phalanx is the one most often fractured, and the distal one the least.

Abnormal mobility and crepitus suffice for diagnosis. A simple fracture will, as a rule, unite in about three weeks. Immobilization may be secured by a slightly curved gutter-shaped, splint of leather, gutta-percha, metal, or felt, secured by adhesive strips or by a roller bandage. (Fig. 61.) Passive motion should be resorted to about the middle or end of the second week. Wrapping the finger, either alone or in company with its uninjured fellow, with a narrow strip of stout paper or textile fabric, coated with collodion or silicate of soda to render it impervious to water, is serviceable.

In compound fractures of the phalanges the wound may become infected, and suppuration and necrosis may take place. Ankylosis may follow in some cases, and in others tetanus may develop. The question of amputation is perplexing in the case of an artisan, to whom a serviceable hand is indispensable,

and also in a female, to whom the preservation of a digit for cosmetic reasons is very important.

A common displacement in simple fractures of the phalanges is angular, with the apex directed forward. If the gutter splint does not afford relief, the fractured bone may be treated by the use of a thick, firm, roller bandage confined in the palm of the hand by strips of adhesive plaster carried over the fingers from the dorsum of the closed hand to the anterior surface of the wrist. In all fractures of the bones of the carpus and digits immobilization should not be kept up too long, as ankylosis is liable to develop.

Fractures of the Pelvis.

According to Treves (*op. cit.*), fractures of the pelvis constitute three per cent of the list of fractures, and consist of those in which the pelvic ring is also fractured and those in which this ring escapes, *i.e.*, of those which involve the true and those which involve the false pelvis (Fig. 62). Although the pelvic bones are to a great extent heavily clothed with muscles, in most cases one should be able, by external examination and by internal digital exploration, —*via* the rectum in the male, and the vagina in the female,—to make a diagnosis of fracture. The complications in these cases relate to coincident injuries of the pelvic viscera and blood-vessels and to those of other parts of the body, which often are of greater importance than the fracture of the pelvis. Involvement of the urinary bladder or the urethra at the same time is important and should be promptly determined because of the liability to and danger from urinary infiltration. Contusion of the large or the small intestine, or of the kidney, may prove to be a serious complication; also laceration of vessels may occasion serious and fatal internal hemorrhage.

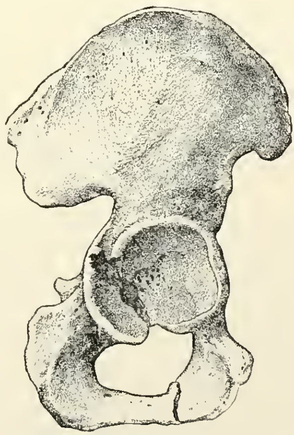


Fig. 62. Horizontal Fracture of the Cotyloid Cavity and of the Ischio-pubic Ramus of the Sacrum, caused by a blow upon the ischium. Experimental specimen. (Walther.)

Causes.—The most frequent cause of fracture of the pelvis is a crushing force, such as the passing of the wheel of a heavily loaded vehicle across the pelvis, the caving-in of an embankment, the falling of slate or stone (in the case of miners and laborers), the kick of a horse, the being caught between the buffers of two railroad cars, etc., and falls from a height. These injuries are due to direct or to indirect violence. Also "violent contraction of the rectus muscle may tear off the anterior inferior spine of the ilium." (Da Costa.)

Symptoms.—While there may be little or no displacement in fracture of the pelvic ring, the following symptoms are often present: great shock, a sense of loss of support, inability to bear the weight of the body on the limb of the injured side, and rotation outward of this limb. Deformity may not be marked, and, if it is, it may be obscured by tumefaction resulting from extravasation. Crepitus may be noticed when the attempt is made to lift the patient, but, if it be sought for, only the gentlest and most careful manipulation should be exercised, for fear of inflicting injury on adjacent viscera. Abnormal mobility may be detected by carefully making increasing direct pressure upon the pubes, or by counter-pressure on the ilia. If these efforts cause pain at a point not pressed upon, this symptom is of diagnostic value. The presence of urinary extravasation of the perineum or the abdominal wall is of great importance and demands prompt relief. The urethra and bladder should be carefully examined with a clean catheter. There may be blood dripping from the meatus, or blood may be passed after the catheter has been introduced, or it may be withdrawn by aid of the instrument. Retention of urine may be a feature from the inception of the injury, and with the lapse of time urinary infiltration into the cellular tissue may show itself. Injury to the rectum will be manifest on exploration with the finger or a speculum, and a change in the contour of the pelvic cavity, the projection of fragments of bone, etc., should readily be detected by the educated finger on rectal examination.

The urethra may be lacerated by fragments of bone, or ruptured by separation of the symphysis. The presence of extravasation will be indicated by pain at the site of the injury, by pain on pressure in the perineum, by retention of urine, by urethral hemorrhage, etc.

Rupture of the bladder will be attended with hypogastric pain, frequent desire to micturate, and the inability to pass urine. A few drops of bloody urine may pass after the catheter has been introduced, or may be withdrawn by the aid of the instrument, and dulness on percussion may be present in the lower abdomen and loin. Evidences of shock are manifest by the paleness and anxious expression of countenance, and by the feeble pulse, cold clammy skin, weak voice, etc. The catheter, when introduced into the bladder, may pass through the rupture into the abdominal cavity. In order to demonstrate the existence of rupture, the bladder should be emptied. Then, if a given quantity of sterile water is injected into it and fails to return, this fact, if accompanied by an increased area of dulness in the lower abdominal zone and loin, may be regarded as a positive indication of the existence of rupture. Palpation of the base of the bladder by the finger introduced into the rectum will furnish important evidence bearing on rupture of the organ.

Treatment.—In fracture of the ring of the pelvis the patient should cautiously be placed on his back on a firm mattress or on a fracture-bed. The examination of the patient should be conducted carefully, in order to prevent

additional injury therefrom to the pelvis and its contents. After the fragments have been as completely reduced as may be practicable, wide strips of adhesive plaster are passed around the pelvis and are supplemented by a wide roller adjusted by compresses carefully arranged so as to prevent undue pressure on bony prominences. A broad padded or quilted swathe, secured by eyelet and lacing or by safety-pins, may be used in lieu of the bandage. The body bandage or swathe should be applied tightly so as to secure as perfect immobilization as possible, without making undue pressure over the abdomen. The patient should be kept on the back for at least four weeks and should remain in bed from two to four weeks longer. At first, the legs should be comfortably flexed and thus supported by pillows. If, however, discomfort is caused, the limbs may be extended, care being taken during the first four weeks to avoid movements that may disarrange the fragments. Firm pillows or sand bags may be placed alongside the body to prevent possible movements during sleep. Long side splints, extending from the axilla to below the feet, may be required to secure immobility in very restless or delirious patients. The binding of the limbs together, after proper padding, may be a serviceable and temporary expedient. If the bedpan is used, it should be managed with great care, to avoid disturbance of the fragments; also a catheter may be necessary to keep the bladder in a proper state.

The various complications are treated in accordance with the principles of general surgery, but the frequency with which the bladder and urethra are involved in these fractures warrants a few brief suggestions at this time. If the urethra or the *bas fond* is ruptured, the resulting urinary infiltration must be promptly relieved by perineal incision and drainage. If the rupture of the bladder is intraperitoneal, abdominal incision and suturing of the rupture will be alike imperative. If the rupture be extraperitoneal, free abdominal section to evacuate the extravasated urine will be required. (For further information, consult the article on "Surgery of the Bladder" in Vol. VIII.)

If the acetabulum is fractured by impact of the head of the femur, extension and counter-extension will be required, as in fractures of the head and neck of the femur, to be subsequently considered.

If the ala of the ilium is broken, the bandage or swathe around the pelvis should not be used, as it may cause displacement of the fragment inward. Under these circumstances place the patient on the back, with the thighs moderately flexed on the abdomen, and enjoin quiet on his part. At the same time keep the seat of the fracture covered with adhesive plaster.

In fractures of the ischium, Hamilton (*op. cit.*) suggests leaving the choice of position to the patient. He says: "Ordinarily he will prefer to lie upon his back with his thighs flexed and supported by pillows, and his hips slightly elevated by a firm cushion laid under the upper part of the sacrum. His knees ought to be gently bound together, but if the patient finds this position painful

or excessively irksome, as sometimes he will, he may be permitted to occupy any position which he finds most comfortable."

In regard to fractures of the pubes, Legros Clarke states that the loose connective tissue between the symphysis and the bladder shows a tendency to develop a suppurative inflammation. The simple forms of fracture in this locality usually show a tendency to unite, and only require immobilization by the means suggested in fracture of the pelvic ring, or by some modification thereof.

Finally, fractures of the pelvic bones, being due to such a variety of traumatisms, necessarily present a great variety of characteristics, and consequently require for satisfactory treatment common sense, aided by a practical knowledge of bone repair and a reasonable amount of mechanical ingenuity in securing immobilization. It is also important to keep in mind the fact that the general physical condition of the patient should be considered, as well as that of the broken bone.

Fractures of the Femur.

According to Gross, fractures of the lower extremity are a little in excess of those of the upper. According to H. H. Mudd, however, "fractures of the lower extremity are about one-half as frequent as those of the upper," "about one-fourth of such injuries being of the femur." Mudd also states that "fractures of the lower end of the femur are infrequent, those of the upper end more common, and those of the middle or shaft most common." According to Messerer, the average tensile strength of the adult femur is equal to about 674 kg. (1482.8 lbs.), while its resistance to lateral pressure is second only to that of the tibia. He further states that it will give way to a torsion force of 89 kg. (196 lbs.).

Fractures of the femur are of great importance to the surgeon and to the patient. With proper care and judicious measures thoroughly carried out, suitable function can usually be secured, although perfect anatomical results may not be. Some shortening is to be expected.

The greatest dangers to be anticipated are unusual deformity, vicious union and non-union, crippling, and possibly even the loss of the patient's life by some remote complication such as fat embolism. The loss of function may be due to deformity, to degeneration or destruction of muscular tissue, to contraction of ligaments and tendons, etc. While, in persons of advanced age, the efforts to secure a useful limb for the few years they may expect to live are most commendable, still these efforts should not be pushed too far, for fear that the patient's expectancy of life may thereby be curtailed. It is in these cases that the patient's physical condition demands as careful study as does the fracture itself.

In considering fractures of the femur, we may divide them into: (1) those

of the upper end, (2) those of the shaft, and (3) those of the lower end. Fractures of the upper end may be divided into: (*a*) intracapsular and extracapsular fractures, (*b*) fractures of the trochanter major, and (*c*) epiphyseal separations of the great trochanter and of the head of the bone.

I. Fractures of the Upper End of the Femur.

When an examination is made for fracture in the vicinity of the hip joint, the patient's clothing should be removed, and he should be placed squarely on the back on a suitable table, or on a bed provided with a firm mattress beneath the centre of which one or more broad boards have been placed, so as to prevent any sagging. The position of the injured limb having been carefully inspected and a comparison made between the two limbs, the surgeon should locate with care the great trochanter and the neck of the bone. The thickness of the muscles of the hip, as well as of those of the greater portion of the shaft of the bone, will, in many cases, render it difficult to locate these parts. Movements to determine unnatural mobility and crepitus must be carefully and gently made, and sudden or violent motion should be avoided. Crepitus may not be apparent, nor is it always essential to the establishment of the diagnosis; but, if present, it is an invaluable sign. If there is reason to believe that impaction exists, the parts should be disturbed as little as possible. Unless great pain and nervousness are present, it will not be advisable to administer an anæsthetic.

Fig. 63.—Intracapsular Fracture of the Head of the Femur. (H. Rieffel, in Le Dentu et Delbet: "Traité de Chirurgie.")

(*a*) *Intracapsular and Extracapsular Fractures.*

Intracapsular fractures of the upper end of the femur (Figs. 63 and 64) vary considerably in many respects. The neck may penetrate the head of the bone, and the fragments may penetrate each other; or they may be intraperiosteal at the junction of the neck and the head of the bone and at the middle of the neck, or extraperiosteal with laceration of the cervical and capsular ligament. In the last-named variety bony union is not likely to take place because of failure of apposition of the fractured ends, of deficient nutrition of the proximal fragment, and of effusion of blood and synovial fluid, and perhaps also on account of interstitial absorption. In the first forms bony union may perfectly well take place; but, unfortunately, these forms of fracture are infrequent.

Intracapsular fractures of the upper end of the femur belong chiefly to advanced life. The alteration of the angle of the neck of the bone with the shaft, the atrophy of the neck and its brittleness, which changes are natural features

of advanced life, are potent predisposing causes of fracture. Intracapsular fracture is unusual in the young. Indirect violence is the chief exciting cause; direct violence, aside from gunshot or penetrating injuries, rarely, if ever, produces it. Females are more subject to intracapsular fracture than males, in the proportion of about two and a half or three to one, and it is therefore sometimes called "old woman's fracture."

While partial fracture of the neck may exist, yet it is certainly very rare; complete fracture of the neck, both within and outside the capsule, without

FIG. 64.—Intracapsular Impacted Fracture of the Neck of the Femur. (Massachusetts General Hospital.)

complete rupture of the periosteum or the capsular ligament, is a common event. In some cases there is not merely a fracture of the bone, but also such a degree of displacement that the capsule is torn. In a majority of cases, however, the periosteum and capsule are only partially ruptured. An intracapsular fracture may be transverse, but as a rule it is slightly oblique, from above downward, and from within outward. In some instances the line of fracture extends from the neck up into the head of the bone, separating a larger or

smaller portion of the latter. In the rare instances in which a fracture within the capsule occurs in early life, it is limited to epiphyseal separations, the result of a fall on the feet or knees, or of some direct injury; the only special feature about such cases being the youthfulness of the patient. In the aged, sometimes the injury results from a very slight jar, or from a twist of the limb, the fracture preceding the fall, to which the injury may be erroneously attributed.

The symptoms of intracapsular fracture are pain, eversion and shortening of the limb, flattening of the trochanteric region, crepitus, and loss of function. The pain may be slight or severe; it is increased in all instances by motion, whether communicated or voluntary. Pain may be localized at or near the joint, and it is sometimes referred to the great trochanter, to the groin, or to the inner and upper part of the thigh. Crepitus is not likely to be present, and should be sought for in a gentle and careful manner. Eversion of the limb is characteristic in many ways and is due to the fact that, being powerless, the limb rolls outward in response to its own weight. In very rare instances, however, inversion has been noticed. In suspected cases in which eversion is absent or not well marked, it will be easy to satisfy one's self that the patient cannot invert the injured limb to the same extent as the sound one. Shortening, to the extent of half an inch and more, is present in nearly all cases, yet in rare instances it may be less than half an inch or so slight as to be scarcely perceptible. In an impacted fracture shortening may not be apparent at first, but after a few days it may easily be appreciated, amounting in some cases to half an inch or more. Shortening usually increases with the lapse of time, and may eventually amount to three inches or more, by reason of displacement and absorption. Unless swelling from hemorrhage or effusion exists, the trochanteric region will appear flattened, and this flattening may even amount to a depression when comparison is made between the injured and the uninjured sides. The great trochanter rises above Nélaton's line, which is drawn directly from the anterior superior spine of the ilium to the greatest prominence of the ischiatic tuberosity. In a normal limb the line passes across the hip just above the top of the trochanter with the thigh slightly flexed. Loss of function is usually quite a prominent feature, and the inability to raise or invert the limb is marked; yet in rare instances, especially if the capsule is untorn or the fracture impacted, the patient may stand on the limb or even walk a few steps, but, as a rule, he can do so only with pain and will soon fall unless supported.

Stimson states that "The posture and appearance of the limb are so characteristic that it is sometimes almost safe to make the diagnosis by simple inspection. As the patient lies upon the back the affected limb appears shorter than the other, everted, and slightly flexed and abducted, and conveys an impression of helplessness that is very often striking."

Altered Arc of Rotation of the Great Trochanter (Desault's sign).—The pivot on which the great trochanter revolves is no longer the acetabulum, and the great trochanter no longer describes the segment of a circle, but rotates only at the apex of the femur, which rotates around its own axis. It is not necessary to obtain this sign, and to do so often inflicts violence on the parts.

Fig. 65.—Extracapsular Fracture of the Head of the Femur. (H. Rieffel.)

Lagoria's sign is a relaxation of the extensor muscles, and the fascia lata too is relaxed.

Ascent of the great trochanter above Nélaton's line, which has already been explained.

Relation of the Great Trochanter to Bryant's Triangle.—Bryant's [Sir Thomas] triangle is laid out as follows: Place the patient in the recumbent posture, carry a line around the body on a level with the anterior iliac spines, draw a line from the anterior iliac spine on each side to the summit of the corresponding great trochanter (*A B*), and measure the base of the triangle from the great trochanter to the perpendicular line (*A C*), to determine the amount of ascent (*B C*). The difference in measurement between the two sides shows the amount of ascent of the trochanter; that is, it shows the extent of shortening of the injured limb. (Fig. 66.)

Morris's measurement shows the extent of inward displacement. Morris measured from the median line of the body to a perpendicular line dropped through the trochanter on each side of the body.

Extracapsular fractures of the neck of the femur (Fig. 65) occur most frequently in middle life, but not so often in old age as those of the intracapsular variety. Extracapsular fractures are encountered more frequently in those under fifty years of age, and in those who are relatively young, than are the intracapsular fractures.

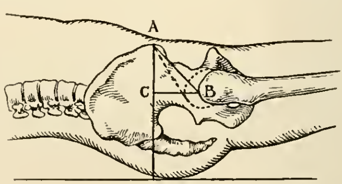


Fig. 66.—Bryant's Method of Making Measurements. (Hoffa.)

The immediate cause of this fracture, in the majority of cases, is a fall or blow on the trochanter, although occasionally it is caused by a fall on the knees or on the feet.

While these fractures may occur at any part of the neck outside of the capsule, the line of fracture is generally found at the base of the neck of the bone, running from the anterior to the posterior intertrochanteric crest, *i.e.*, where the bone is weakest. It is proper to say in this connection that a fracture at the base of the anatomical neck of the femur is quite likely to be intracapsular

in front and will be extracapsular behind for obvious anatomical reasons relating to the connection of the capsule with the bone at that situation. Hoffa states (Von Bergmann's "System of Surgery," American edition, Vol. III., p. 437) that strictly extracapsular fractures of the neck of the femur are extremely rare, the majority of those thus designated being in reality mixed fractures—*i.e.*, partly intracapsular and partly extracapsular. In many cases the proximal or acetabular fragment penetrates the trochanteric or distal one, splitting it into two or more pieces. Hamilton (*op. cit.*) says: "The direction of the lesion in the outer fragment preserves also a remarkable uniformity; the trochanter major being divided from near the centre of its

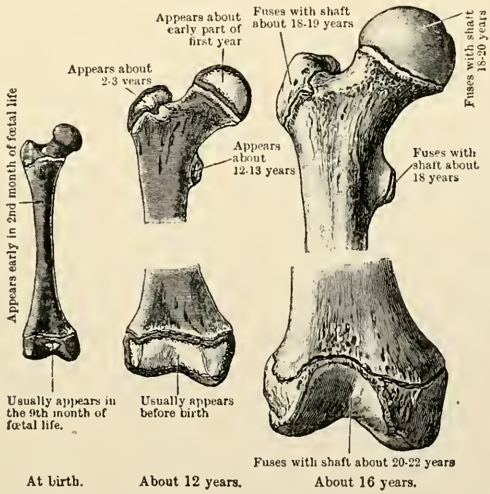


FIG. 67.—Ossification of Femur; Condition at Different Ages. (Cunningham.)

summit, obliquely downward and forward toward its base, and the line of fracture terminating a little short of the trochanter minor, or penetrating beneath its base; while one or two lines of fracture usually traverse the trochanter major horizontally." He further states "that, in the examination of more than thirty specimens, I have noticed but two or three exceptions to the general rules above stated." A study of the development of the femur shows that the trochanter major, which appears as an epiphysis about the second or third year, and fuses with the shaft about the eighteenth or nineteenth year, has, near its centre, primarily a wedge-shaped projection that penetrates the shaft in the direct line so often marked in later years by this fracture (Fig. 67).

The trochanter is usually turned backward, the shaft of the bone rotating in that direction as in other fractures of the neck of the bone. Malgaigne claimed that impaction, with resulting fracture of the trochanters, always occurs in true extracapsular fractures, except in the very rare instances in which the trochanter forms a part of the upper or proximal fragment. While this is not finally accepted, it is nevertheless established that impaction or comminution of the trochanter is the rule, whether the injury is produced by a force exerted directly by way of the foot or knee, or by one applied directly to the trochanter. If the limb is in good position after impaction, and the impacted state persists, the best plan is to maintain the extremity in that position. The limb will of course be somewhat shortened, and the extent of this shortening will vary from an insignificant to a considerable amount, according to the degree of the force which produced the impaction. In the majority of cases it will be found that the limb is rotated outward, and only in rare instances is it rotated inward. This latter deformity appears not to depend entirely on any one special cause. Then, again, in a certain number of instances the limb will be neither everted nor inverted. That these different positions may often depend upon the direction in which the fracturing force was exerted and upon the direction and degree of impaction, is no doubt true. Voluntary or involuntary movement of the patient, injudicious handling of the limb by the surgeon or by the attendants, and, more especially, rotating the limb forcibly for the purpose of determining the existence of crepitus or of mobility, are objectionable because they release the fragments of bone, thus causing greater mobility at the seat of the fracture, a greater degree of shortening, and eversion of the limb so common in fractures of the neck of the femur.

Symptoms.—The symptoms, briefly stated, are pain, mobility, crepitus, shortening and eversion of the limb. In the absence of impaction, displacement is marked. In rare instances, some one or more of these symptoms may be absent. There will be flattening over the region of the trochanter, more especially if impaction is not present, and the limb will rotate on a much shorter axis than that of the sound side. Pain, tenderness, and swelling are commonly located at the outer and upper part of the trochanter. The limb can be freely moved by the surgeon when there is impaction or when there is no impaction, but the motion will cause more or less pain and muscular spasm. Therefore needless movements should be avoided, for apparent reasons. Voluntary motion is either wanting or exists in limited degree. Crepitus usually is present in varying degrees unless impaction is present and the fragments are firmly fixed. Shortening is invariably present in complete fracture and varies from an inch, in most cases, to an inch and a half or more, depending on the direction and the degree of force connected with it. In cases with impaction the shortening may not exceed half an inch.

In the majority of instances the line of fracture is both within and outside

the capsule, and the accompanying symptoms may indicate whether the fracture is chiefly intracapsular or chiefly extracapsular. The prognosis, especially as to bony union, will be more favorable if the line of separation is mainly outside the capsule.

(*b*) Fracture Through the Trochanter Major.

In this form of fracture the lines of separation vary somewhat, in the one instance passing through the trochanter or below it, so that the upper fragment is composed of the head and neck of the femur and the upper part of the trochanter, while in other instances it may be obliquely directed from within outward and upward, or from behind in an upward course, or it may pass obliquely through the trochanter, downward and inward, and not involve the neck. Under proper immobilization and apposition, kept up for from six to eight weeks, bony union, in most instances, should follow. The symptoms partake largely of those common to extracapsular fractures, viz., pain, crepitus, shortening, abnormal mobility, and the characteristic deformity that would be naturally expected to follow division of the bone along this line.

(*c*) Epiphyseal Separation of the Trochanter Major.

Epiphyseal separation of the trochanter major is more common than the last-named injury, and, like it, is due to direct violence. The distinguishing features are the age of the patient (the epiphysis being formed about the fourth year, and fusing with the shaft at the eighteenth); local pain, tenderness, and swelling; mobility of the fragment; and crepitus, if the fragment can be brought in contact with the corresponding part of the femur. Displacement may also be present, but it is likely to be limited, especially when the limb is abducted; yet the fissure between the fragment and the shaft may be felt when careful palpation is made. There is no shortening, and free passive movement and the full weight-sustaining function of the limb are present. Although the prognosis is favorable in the great majority of instances, Treves states (*op. cit.*) that "Hutchinson collected 11 cases, 6 of which suppurated and 5 died."

Fractures of the trochanters are infrequent, the trochanter major being the one more often thus injured. This portion of the bone may be fractured by direct or by muscular violence. The fragment may be free or be restrained by tendinous or periosteal tissue, and is usually displaced backward and upward. Mobility of the fragment, pain on locomotion, and external rotation are usually marked. Fracture of the neck of the bone may be associated with fracture of the trochanter. Immobilization with the limb abducted and rotated outward, and local pressure, constitute the main features of the treatment.

Fracture of the trochanter minor may happen, though rarely, with fract-

ure of the neck. Muscular violence is reported to have caused it. Without x-rays the diagnosis is wellnigh impossible. When the injury occurs independently of fracture elsewhere about the neck, flexion of the thigh with external rotation will serve to approximate the fragments.

Separation of the upper epiphysis, or of the head of the femur, is a rare result of traumatism, occurring most frequently in connection with disease of the bone. It belongs entirely to early life, and is followed by marked permanent shortening, or sometimes by coxa vara. The symptoms are substantially those of intracapsular fracture. The crepitus, if present, is of a cartilaginous rather than of a bony kind.

Differential Diagnosis of Fractures of the Neck of the Femur.

The differential diagnosis of a fracture of the neck of the femur is a matter of great importance, and in the Roentgen or x-rays we possess the most valuable means for the purpose. Before determining the treatment to be pursued we should, whenever practicable, employ this means of diagnosis. Unfortunately, the x-rays are not always available; and, furthermore, the radiographs of this injury do not always furnish entirely satisfactory evidence of the precise location and extent of the fracture. Under these circumstances the diagnosis will have to be made by a careful study of the shape, the relations, and the functions of the bones that form the hip joint, of the muscles that control the limb, and of the ligaments that are connected with the joint. Such a study, combined with a knowledge of the signs and symptoms belonging to the various fractures, should suffice.

The practical tabular arrangement of the late Dr. Frank H. Hamilton has been of material service to me in past years, but later observations justify in some instances a modification, and I submit the following as more in accordance with the accepted facts of to-day:

Table of Signs of Fracture in Intracapsular and Extracapsular Fractures of the Neck of the Femur.

Intracapsular.	*Extracapsular.*
1. More often after the 50th year of age, and its frequency increases with age.	1. While found in old age, may occur at any age.
2. More frequent in women.	2. Equally common in both sexes.
3. Occasioned by slight force (indirect), and the same applied in the long axis of the femur, as in the case of a fall on the foot or a trip on the carpet, etc.	3. Occasioned by greater violence (direct), and the same is applied in the long axis of the neck, as in the case of a fall on the trochanter.
4. Pain, swelling, extravasation of	4. Pain, swelling, extravasation of

blood, and ecchymosis more often in the inguinal region.	blood, and ecchymosis more often at the outer and upper part of the trochanter.
5. Sometimes the patient can flex the thigh or draw up the heel, but he cannot lift perpendicularly the foot from the bed.	5. Flexing the thigh or drawing up the heel is so painful that the patient will not voluntarily attempt it.
6. Shortening at first is less than it is in extracapsular fracture—not more than half an inch or three-quarters of an inch, sometimes not any. Shortening, with the lapse of time, increases, and then may be greater than in extracapsular fracture.	6. Shortening at first is greater than in intracapsular fracture and does not increase. When the fracture is not impacted, the shortening may be an inch and a half or more.
7. Crepitus rarely can be determined, and the diagnosis is made ordinarily by the history of the injury, by the relations of the great trochanter to Nélaton's line and to Bryant's triangle, and by the use of the x-ray.	7. Crepitus is more or less distinct (except in impacted fractures), and with this and other general and special signs a diagnosis can usually be made; the use of the x-ray often fails to furnish satisfactory evidence.

In cases in which we are deprived of the advantages of the x-ray, the diagnosis depends principally on the nature of the violence, the age and sex of the patient, and the deformity of the limb, factors which have been so fully considered in the preceding pages as not to require repetition here. I might state here, however, that at the present time there are many surgeons who hold the view that it is not particularly important to determine whether the fracture is extracapsular or intracapsular; that it is enough, for all practical purposes, simply to ascertain whether there is or is not a fracture of the neck of this bone; and that, in reaching a conclusion upon this latter point, the chief reliance should be placed on the results obtained from careful measurements of the sound and the injured limbs.

It is proper again to enjoin the exercise of great care in these cases, for error may result in irreparable damage to the patient's physical condition and comfort, and also to the reputation of the surgeon.

A severe contusion over the region of the hip will produce swelling, with accompanying deformity, often eversion, pain, and some loss of function, and the diagnosis of such a condition from intracapsular fracture without separation of the fragments, and also of impacted fracture of the neck, is often difficult. The loss of function in a contusion is rarely so complete as in fracture and is more limited in its duration; and, furthermore, the usual eversion may be wanting and there is no shortening of the limb nor alteration of the trochanteric relations. Although the use of an anæsthetic in examining a supposed fracture at the hip joint is objectionable, there are exceptional cases in which it may be required for a thorough examination. Even in these cases there is danger that, owing to the patient's unconsciousness of pain, the surgeon may yield to the temptation to employ too much force in his manipula-

tions, and thus cause a separation of the fragments. It is this very danger which has prompted the advice to treat these doubtful cases, if no contra-indications exist, as if they were in reality cases of fracture. The combination of a contusion and a rheumatic joint offers special difficulties in diagnosis. A dislocation of the head of the femur on the dorsum ilii may sometimes closely resemble a fracture, especially when great contusion or extravasation of blood has occurred about the joint, with possibly a fracture elsewhere about the hip. In such a dislocation, however, some inversion is invariable; and, although there is a shortening of from one to three inches, and the great trochanter is above Nélaton's line, there are usually other evidences which point to a dislocation rather than to a fracture—such, for example, as a history of forcible internal rotation and the facts that the head of the bone is found resting on the dorsum of the ilium, and that the trochanter rises toward the iliac spine. A dislocation into the thyroid foramen may show eversion, but there is then distinct lengthening. In fracture of the brim of the acetabulum there will be shortening of the limb, but, unless resulting dislocation on the dorsum complicates the fracture, the power of everting and adducting the limb will still remain. In fracture of the cotyloid cavity, caused by impact of the head of the femur, there will be shortening of the limb, but the deformity can be detected by rectal exploration with the finger.

Treatment of Hip-Joint Fractures.

In many of these cases of fracture of the femur in the region of the hip joint, the treatment will be directed along similar if not identical lines, even when the fractures are of different varieties. In a few instances, however, the difference between the plans of treatment required will be both marked and material. For example, in the case of a fracture in an aged woman or man, in whom the circulation and all the natural processes are feeble, it would be unwise to adopt a plan of treatment that would necessitate confinement to bed or the annoyance and worry of an immobilizing apparatus of any kind. Usually the best that can be done for such cases is to restrict the confinement to bed to a limited period of time; to arrange matters in such a way that physical discomfort shall be reduced to a minimum, that the danger of bed-sores shall be avoided, and that the fractured limb shall be kept in as nearly normal position as possible by means of sand bags, pillows, and cushions; and, finally, that a moderate degree of extension shall be employed from the leg and ankle by means of a pulley at the foot of the bed. Under a régime of this kind, maintained for a week or ten days or possibly longer, one may reasonably expect that the injured patient will become somewhat inured to the unusual and discomforting state of affairs. A moderate degree of counter-extension can be secured by slightly lowering the head and shoulders of the patient, or by raising

the foot of the bed. These arrangements need not deter the patient from turning in the bed or from indulging to some extent in other movements of the body, provided they do not cause too much pain. As soon as these movements of the body can be accomplished without depressing pain, the patient should be taken out into the open air, on suitable occasions, in a wheeled chair, and later should be encouraged to use crutches. Attention to the secretions, diet, cleanliness, etc., of the patient, although apparently a trivial matter, is in reality one of the important duties of the surgeon. It should be understood clearly from the first, by all concerned (and particularly by the patient's friends), that the injury is of such a nature that during the remainder of life he will have a halting gait, that a bony union of the fractured bone cannot be secured, and that illogical efforts to secure such a union serve to imperil the patient's life. The suggestion that all such injuries in suitable instances may be treated by open incision and the removal of the upper fragment of bone is unwise and has not my approval, for it has been demonstrated frequently that this frag-

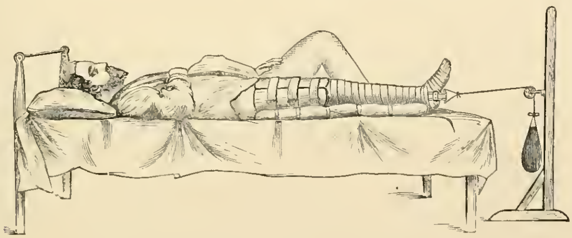


Fig. 68.—Buck's Extension Apparatus in Position.

ment may become absorbed and that the opposing ends of the fractured bone may become rounded off. Cases have been observed in which the upper fragment forms a distinct cup-shaped cavity in which the rounded end of the lower fragment moves. In certain cases, however, it may be found necessary, because of inflammation and severe pain, to open into the joint and remove the detached fragment. In some compound injuries here it is essential to remove the loose fragments and also the detached head of the bone. In these cases the surgeon should be guided, in treatment, by the approved principles of surgical experience. In simple fractures within the capsule the formation of "callus" does not take place. If the head of the bone, by reason of the extent of the rupture of the capsular ligament and periosteum, is deprived of the blood supply necessary to secure proper union, the blood received through the ligamentum teres, when present and uninjured, will not suffice for the reproduction of osseous tissue. Osseous union should not be promised, no matter how patient and thorough the treatment may be. If the fracture is one in which the line of solution extends both inside and outside the capsule, some callus will

likely form at that part (posteriorly) of the line of the fracture which lies outside the capsule.

In an epiphyseal separation of the head of the femur resulting from disease, the pathological condition of the acetabulum, or upper end of the femur, may require opening of the joint, for removal of the loose head of the bone.

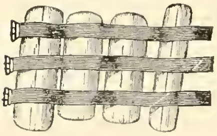


Fig. 69.—Coaptation Splints, for Use in Cases of Fracture of the Femur.

In fractures at the upper end of the femur in which ligamentous or fibrous union may be reasonably expected to take place, the following method of treatment will give good results: Keep the patient in bed with a Buck's extension and Hamilton's long side splint (Figs. 68, 69, and 70) for the first ten days or two weeks, during which time the pain, tenderness, and swelling will have subsided to a great extent; then put the limb in a plaster-of-Paris spica, and get the patient out of bed on crutches. In some instances good union is secured by applying a plaster-of-Paris encasement as early as the first or second day after the injury; still I am convinced that the method mentioned above is the better and much the safer one.

Some surgeons prefer to use a Liston's straight splint for the entire period of the treatment (Fig. 71). I cannot, however, commend it.

Fractures of the upper extremity are not so well treated by plaster of Paris as are those of the lower. I regard it as invaluable in the treatment of fractures of the lower limb, especially in those which are now under consider-

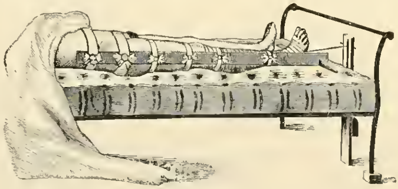


Fig. 70.—Hamilton's Long Side Splint, with Traction.

ation. It not only gives excellent results as to bony union and restoration of function, but it adds materially to the comfort of the patient, and has lessened, it appears to me, the mortality of these injuries. Before the plaster dressing is applied, however, it is better to wait until all the unpleasant features relating to fracture have disappeared or have been brought under control. The dangers of faulty apposition, of gangrene, and those of other conditions belonging to a recent traumatism should have disappeared before the dressing is applied.

Gurdon Buck's method of treating fractures of the thigh by extension,

with modified details, is quoted from Scudder's excellent work on "The Treatment of Fractures":

"The materials needed are two strips of *adhesive plaster*, each two inches wide and long enough to extend from the seat of fracture to the internal malleolus. . . . To each strip of plaster at the ankle end should be stitched a piece of webbing the width of the plaster and about six inches long. Prepare five other strips of adhesive plaster, all of which should be one inch and a half wide. Three of these strips should be long enough to encircle respectively the leg above the malleoli, the knee above the condyles, and the thigh an inch below the seat of the fracture. The remaining two strips of plaster should be long enough to extend spirally from the malleoli around the leg and thigh to the seat of fracture. Prepare also a *roller bandage* of gauze or cotton cloth, a curved or straight *ham splint* [inferior] properly padded, and three adhesive strips for holding the ham splint.

"In addition, three long *coaptation splints* for surrounding the shaft are required, also six webbing *straps* with buckles or strips of bandage to be used as straps;

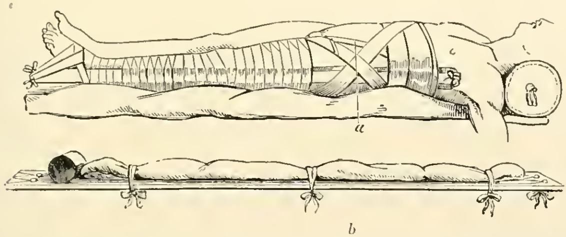


Fig. 71.—Liston's Splint, Padded and Applied. *a*, Perineal band; *b*, splint shown separately.

fresh *sheets* or pillow-cases or towels for padding; a *swathe*, to encircle the pelvis, made of unbleached cotton cloth or medium-weight Shaker flannel; and a long outside *splint of wood*, four inches wide, to extend from the axilla to six inches below the sole of the foot. To this last a cross-piece, eighteen inches long, should be fastened, making thus a long T-splint. The list is completed by *two towels* for perineal straps, *safety-pins*, and a *pulley*, which can be bought at little cost at a hardware store. This pulley should be screwed to a *broom-handle* cut to the right height. . . . A *spreader*, which is a piece of wood two inches wide and a little longer than the width of the foot, perforated at its centre for the extension-weight cord, is also required. There should be provided: a *cord*, three feet long, size of a clothes-line; two bricks or wooden blocks for elevating the foot of the bed; four sand bags twenty inches long and six inches wide; a *cradle*—for keeping the weight of the clothes from the thigh. [The cradle may be made of two barrel hoops cut in two and attached at the middle, or the halves of several barrel hoops attached at their ends.]

"*Application of Buck's Extension, with Modified Details.*—All the materials being in readiness and at hand, the patient having been etherized (?) and the fracture examined, the thigh and leg and foot are first washed with warm water and Castile soap and thoroughly dried [the thigh and leg shaved]. The long straight strips of adhesive plaster with the webbing attached are applied to the middle of the two sides of the leg and thigh up to the seat of fracture. The junction of the ad-

hesive plaster and webbing should be brought to a point just outside the malleoli. The two spiral and then the three circular strips should next be applied as indicated. [The spiral strips, beginning just above the malleoli, should pass around the leg in opposite directions, in a spiral manner, until they reach each other, just below the fracture; the circular strips should pass around the thigh and leg so as to increase the adhesion of the long straight strips to the leg and thigh.] Over the extension strips is placed a roller bandage, snugly and evenly surrounding the foot, the leg, and the thigh. The bandage fixes the adhesive plaster, prevents swelling of the foot, and affords comfort. Then the padded posterior coaptation or ham splint is applied and held by three straps of adhesive plaster, one at each end of the splint and one below the knee. If the curved ham splint is used, the padding (one sheet of wadding) should be laid upon the splint evenly throughout. If a straight ham splint is used, the padding should be applied evenly, and, behind the knee, should be placed an additional pad in order to support the knee in its natural position. This additional pad should be placed between the splint and the layer of sheet wadding. The tendency of the padding of the ham splint is to slip away from each end of the splint, thus leaving it unduly pressing into the thigh and calf. It is wise, therefore, to hold this padding in place by strips of adhesive plaster at each end of the splint. The three thigh coaptation splints should be next put in position—one anteriorly, extending the whole length of the thigh from groin to patella; one externally, extending from trochanter to external condyle; and one internally, extending from just below the perineum to just above the adductor magnus tubercle. The best padding for these splints is a towel folded lengthwise of the splints. The splints themselves are held by an assistant while three or four straps are tightened sufficiently to hold them in place. While these coaptation splints are being applied it is very important that steady traction be made upon the lower fragment in order to maintain its reduction. The straps of the coaptation splints are then finally tightened. The long outside splint with the T cross-piece is then padded with sheets and applied to the limb and body. The upper end of the splint is enclosed in a swathe, which passes around the body and is fastened with safety-pins. The thigh and leg are held steadily to the outside splint by two or three straps. The assistant, making extension, exchanges his traction for that of the weight and pulley. The foot of the bed is raised upon blocks or bricks, in order to provide the counter-extension by means of the weight of the body. The foot is kept at a right angle with the leg. The sand bags are laid along the inner and outer sides of the limb to add greater steadiness to the apparatus."

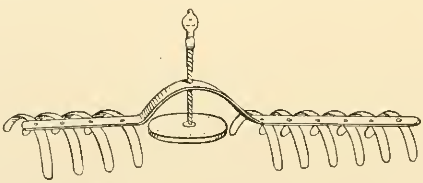


Fig. 72.—Senn's Apparatus by Means of which Graduated Pressure can be Brought to Bear upon the Neck of the Femur in the Direction of the Long Axis. (Hoffa.)

Scudder makes the further statement that throughout the course of the treatment it is essential to be positive about four things: Absence of shortening, which is prevented by the weight and pulley; outward bowing of the thigh, which is prevented by slightly abducting the limb after the apparatus is applied; outward rotation of the limb, which is prevented by fastening (by means of pins) a piece of bandage six inches wide to the leg, below the calf, bringing it up on the outer side of the leg, and securing it to the long splint while the limb is held in the corrected position; and sagging backward of the thigh, which is prevented by the posterior ham splint properly padded. The weight to be employed may very conveniently consist of a bag of shot, the weight of which should only be sufficient to maintain satisfactory extension. In actual practice this varies from five to about twenty pounds.

The inflammatory swelling, pain, etc., having been controlled in a reasonable degree by the end of the second week after the injury, I usually encase the limb permanently in plaster of Paris according to the method of Senn, which is thus described by Da Costa:

"Senn claims that by his method of 'immediate reduction and permanent fixation' bony union is obtained in fractures of the neck of the femur within the capsule. He 'places the patient in the erect position, causing him to stand with his sound leg upon a stool or box about two feet in height; in this position he is supported by a person on each side until the dressing has been applied and the plaster has set.'

"Another person takes care of the fractured limb, which, in impacted fractures, is gently supported and immovably held until permanent fixation has been secured by the dressing. In non-impacted fractures the weight of the fractured limb makes auto-extension, which is often quite sufficient to restore the normal length of the limb; if this is not the case, the person who has charge of the limb makes traction until all shortening has been overcome as far as possible, at the same time holding the limb in position, so that the great toe is on a straight line with the inner margin of the patella and the anterior superior spinous process of the ilium. In applying the plaster-of-Paris bandage over the seat of fracture a fenestra, corresponding in size to the dimensions of the compress with which the lateral pressure is to be made, it left open over the great trochanter.

"To secure perfect immobility at the seat of fracture, it is not only necessary to include in the dressing the fractured limb and the entire pelvis, but it is also absolutely necessary to include the opposite limb as far as the knee, and to extend the dressing as far as the cartilage of the eighth rib. [A 'dinner pad' should be applied over the hypogastric region; it should extend up to the umbilical region.]

"The splint (Fig. 72) is incorporated in the plaster-of-Paris dressing, and it must be carefully applied, so that the compress, composed of a well-cushioned pad with a stiff, unyielding back, rests directly upon the trochanter major, and the pressure, which is made by a set-screw, is directed in the axis of the femoral neck. Lateral pressure is not applied until the plaster has completely set. Syncope should be guarded against by the use of stimulants.

"No matter how snugly a plaster-of-Paris dressing is applied, as the result of

shrinkage it becomes loose, and without some means of making lateral pressure it would become necessary to change it from time to time in order to render it efficient. But by incorporating a splint in the plaster dressing (Fig. 73) this is obviated, and the lateral pressure is regulated, day by day, by moving the screw, the proximal end of which rests on an oval depression in the centre of the pad."

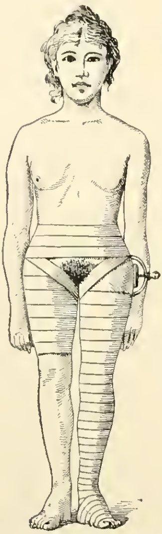


Fig. 73.—Senn's Apparatus in Position.

Thomas' splint (Fig. 74) is warmly advocated for this purpose by some authorities, and it is a good appliance; it permits readily the using of a bedpan and allows the patient to be turned over on the side when it is desired to smooth the bedclothing. Thomas' splint is made as follows: A bar of soft iron, one inch and a half wide, three-fourths of an inch thick, and long enough to extend from the lower fourth of the leg up to the axilla, is moulded to fit the posterior surface of the limb and body. At its upper and lower ends a transverse band or collar of lighter iron is securely fixed, the one encircling the chest just below the axilla, and the other the leg just below the swell of the calf. A third band passes around the thigh just below the perineal crease. It may be modified to some extent to suit the peculiarities of an individual case. A piece of strong bandage is passed around the perpendicular bar just below the upper transverse collar and carried thence over the shoulders. To prevent it from excoriating the latter, it is run through two pieces of thick rubber tubing. A roller bandage around the calf and another around the thigh, with a spica and compress over the trochanter major if thought necessary, will secure efficient immobilization, and the patient can be got out of bed, with this splint, sooner than with any other dressing except the plaster-of-Paris splint. If thought necessary, extension may be made by weight and pulley during the first two or three weeks. If the patient is to move about, the opposite limb may be prac-

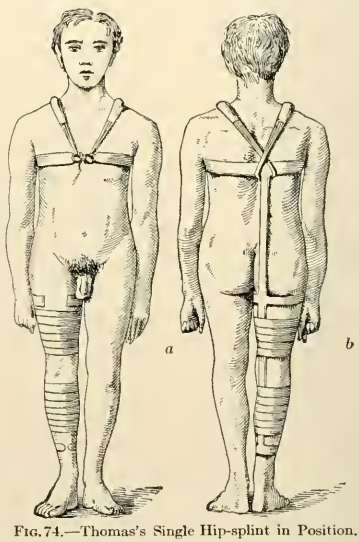


Fig. 74.—Thomas's Single Hip-splint in Position. (After Ridlon.) *a*, Front view; *b*, rear view.

tically lengthened by the wearing of a platform or thick-soled shoe, thus raising the injured one so that the weight of the limb will exercise an extending influence, aided. if need be, by additional weight applied to the sole.

The Nathan R. Smith anterior splint (Fig. 75) has its advocates, but Hodgen's modification of it (Fig. 76) is regarded by many as a better method. The former is described in the older works on surgery and in some of recent date; Hodgen's splint is described in most surgeries. This brief reference seems to me to be all that is necessary, especially as the illustrations show the peculiar characteristics of the apparatus. The principle involved is that of the double inclined plane, the limb being suspended and the direction of the suspending cords being such as to secure both apposition and extension. Brown, of

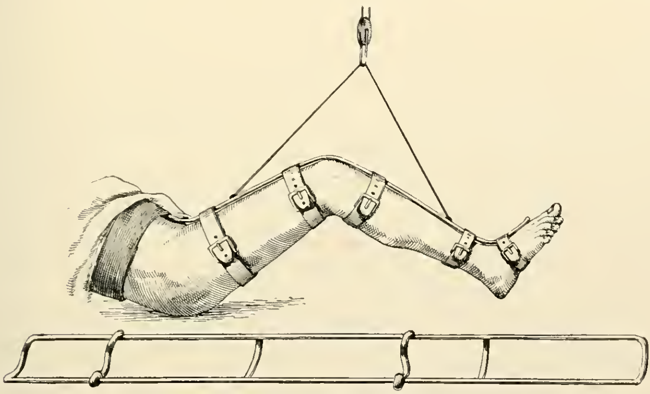


Fig. 75.—Nathan R. Smith's Anterior Splint.

Birmingham, Ala., claims that it is one of the most satisfactory methods of treating fractures of the thigh below the upper third.

The method of treating fractures of the neck of the femur advocated by Whitman, of New York, seems to me to be one from which good results may be expected. At present, however, it is still too soon to pass judgment on this method, which, to use the doctor's own expression, "appeals to our reason rather than our experience." Ashcroft, of Deadwood, S. Dakota, reports the case of a miner, aged 42, weight 190 pounds, height 5 feet 10 inches, who sustained an intracapsular fracture of the neck of the femur in consequence of a mass of stone falling upon him. Whitman's method of treatment was followed and an excellent result was secured. The Whitman method is described as follows:

A piece of ordinary seamless shirting, such as is used for plaster jackets, about six feet in length, cut and sewed in shape to cover the body and limb, is first applied and fixed securely in place by bands passing over the shoulders. This is threaded

with several long bandages, the "scratchers" designed to keep the skin in good condition. It is also advisable to insert a substantial "dinner pad." The patient is then anæsthetized and is placed in a position for the application of the bandage. The head and shoulders may be supported conveniently on a box of proper length and about eight inches in height; the pelvis rests upon a sacral support. A wide, firm band of cloth is then carried about the perineum, the two ends of which, united over the shoulder and held by an assistant, furnish counter-traction. If the fracture is complete, the shortening is first entirely overcome by the traction and counter-traction. The limb, in the extended attitude, under traction is slowly abducted by the assistant until the trochanter is fairly opposed to the side of the pelvis, forty-five degrees from the line of the body, the operator meanwhile pressing the trochanter downward and inward. In some instances there is a distinct snap as the outer part of the neck slips beneath the rim of the acetabulum, and in any event the abduction is increased until the trochanter is firmly apposed to the side of the pelvis. The abductor muscles are relaxed and the direction of the iliopsoas is so changed that muscular contraction can no longer exert a harmful influ-

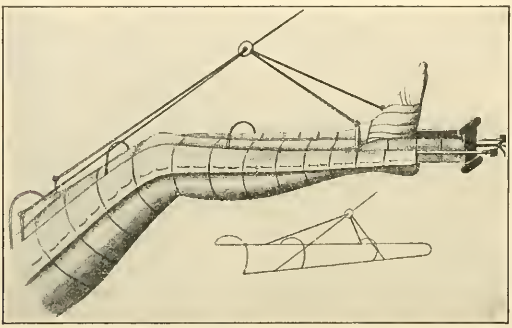


FIG. 76.—Hodgen's Modification of the Nathan R. Smith Splint Applied.

ence. The primary object of the abduction is, by leverage against the upper border of the acetabulum, to overcome the deformity; secondly, by tension on the capsule, to remove folds, to appose the fragments, and by actual contact of bone with bone to oppose redisplacement.

A plaster spica bandage is then applied in the usual manner from the mammary line to the toes; this should fit snugly about the hip, and, most important of all, should completely enclose and support the buttock. As a rule, the support is comfortable because it is efficient. It absolutely prevents rotation of the limb. The support may, at the end of four weeks, be shortened, to allow action at the knee, and, at the end of eight weeks, or when it may appear that union is assured, it may be removed. The best time for the application of the treatment is immediately after the injury, for with the comprehensive support of the whole limb, from the toes up, there is little danger of constriction.

The plaster-of-Paris dressing as applied by Senn should be continued for two, two and a half, or three months, or in some cases for a longer period,

occasional removals and reapplication being required to meet the shrinkage of the limb, and for purposes of cleanliness. The Thomas hip splint (Fig. 74) should be kept on for eight weeks at least, and in some cases for a longer time; and, even after the removal of either the Senn or the Thomas dressing, the patient should spend at least a month with only a limited amount of use of the limb, the greatest care being taken to avoid sudden undue pressure on the reunited bone until it is securely consolidated. Too early use of the limb is no doubt a frequent cause of both unnecessary shortening and deformity.

In this connection the following is of special interest:

The results obtained by Moore in treating fracture of the femoral neck after the method devised by Maxwell were very satisfactory. The plan is as follows: The patient is anæsthetized, the thigh flexed upon the body and lifted up so as to pull the psoas and iliacus muscles away from the seat of fracture: extension is kept up while the limb is being brought down to its natural position; a pull of from fifteen to twenty-five pounds is applied by means of Buck's extension. Another pull of from ten to fifteen pounds is then applied to the inner side of the upper end of the thigh by weight and pulley. The direction of the latter pull is upward and outward. The elevation of the side pulley must be such as to overcome the outward rotation. Stiffening of the knee is prevented by removing the weights every three or four days and flexing the knee. It is reported that bony union has thus been secured in practically all cases of fracture of the femoral neck. (*St. Louis Courier of Medicine*, Nov., 1896.)

Cobb reports a case of an ununited fracture of the neck of the femur which he treated by operation, and in this report he presents the following conclusions, which are submitted without comment to the experience and judgment of the profession, as a suggestion of what can be done:

(1) Fractures entirely intracapsular are very rare. (2) When they do occur and are unimpacted, the obtaining of union by any form of fixation apparatus is exceedingly doubtful. (3) The operation of nailing the fracture with or without open incision is to be adopted whenever possible. (4) In the young and middle-aged, when no contra-indications to operation are present, such as obesity, general debility, marked arteriosclerosis, or complicating disease, the method with open incision is more accurate and preferable. (5) In persons of advanced age and those with definite contra-indications to surgical interference, the direct method without incision, as practised by Nicolaysen, should be used in all cases if seen sufficiently early. (6) In employing the method of Nicolaysen, a general anæsthetic should be given.—*Boston Medical and Surgical Journal,* May 10th, 1906.

In fractures of the neck and of the shaft of the femur in children, the natural restlessness of the patient is with difficulty overcome. To meet this condition, Hamilton has made a recommendation which I have found very serviceable; he advises the use of a long side splint on the sound limb as well as on the injured one, the ends projecting beyond the feet to be firmly attached by a cross-piece of wood. Some prefer this plan to the Van Arsdale's triangle or Bry-

ant's method of vertical extension of the thighs and legs at right angles to the body. Da Costa advises Buck's extension for four weeks, followed by a plaster-of-Paris dressing for four weeks longer.

II. Fractures of the Shaft of the Femur.

Fracture of the shaft of the femur may occur at any point of this part of the bone and at any age of life. It occurs most frequently at the middle third, next at the lower, and least often at the upper third. The fracture may be a transverse one, is more frequently oblique, is sometimes spiral or rotatory, and, in the dense part of the shaft, gunshot injuries produce stellate and in rare instances "butterfly fracture." (See article on "Gunshot Wounds" in Vol. II.) Separation of the lower epiphysis sometimes occurs. The common causative factor, in fractures of the upper third of the femur, is indirect force; in fractures of the lower third, it is usually direct force; and in those of the middle third, both direct and indirect force may cause fracture. In rare instances muscular action alone has produced fracture of the shaft. Fractures of the shaft of the femur are common to all periods of life, are more numerous before ten years of age, and then diminish in frequency with the progress of age.

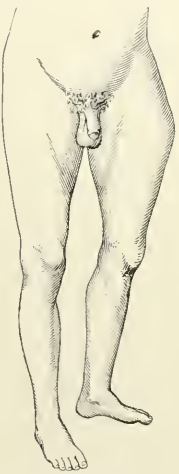


Fig. 77.—Fracture of the Shaft of the Femur, with Shortening and Rotation Outward of the Limb. (Hoffa.)

The symptoms of fracture of the shaft of the femur are quite characteristic, and the diagnosis is usually made with ease. There is generally marked displacement, except in cases of impaction (rare), in cases of children, in cases in which the fracture is transverse, and in cases in which the periosteum remains intact. Shortening, except in cases of impaction and in transverse and green-stick fractures, is quite characteristic; and the swelling which is visible immediately after the fracture, before inflammation sets in, is due to shortening and will be in proportion to the amount of shortening. A little later, inflammatory swelling adds its portion to this deformity. Deformity, abnormal mobility, pain, tenderness, and crepitus are usually present. The shortening is due to the contraction of the hamstring and quadriceps muscles; and the angular deformity is also caused by the action of these muscles. The upper fragment, in a fracture of the upper third, points upward and outward, owing to the unopposed contraction of the iliacus and psoas muscles. As a rule, in fractures of the shaft of the femur, the lower fragment is drawn upward, and behind as well as to the inner side of the lower end of the upper fragment. In fractures of the lower third, the gastrocnemius, when pulling upon the condyles, tilts the lower

fragment backward, causing its upper end to project toward the popliteal space, with possible injury to the great vessels of this region. Eversion of that part of the limb which is below the fracture (Fig. 77) is the rule, as in fractures of the neck; but there are occasional and rare exceptions in which this part of the limb may be inverted, or may be in its usual line. The shortening, in adults, may amount to two or three inches; in children it is proportionally less. The sharp end of a fragment may perforate the overlying tissues as the immediate result of the exciting force, or this perforation may be caused by a fall or by the movements of the individual subsequently to the breaking of the bone.

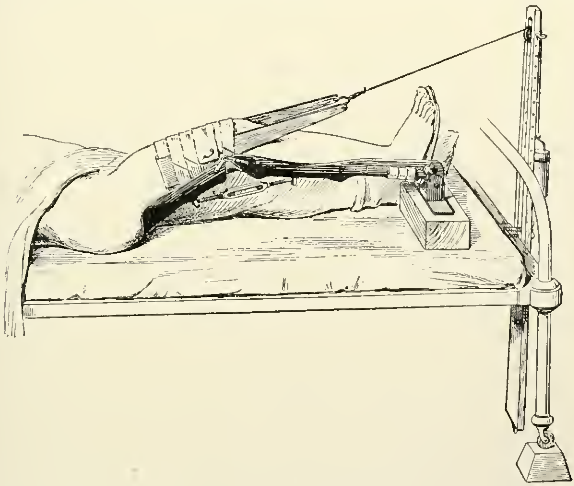


FIG. 78.—Weight Extension for Fracture of the Femur below the Trochanters. (From Cheyne and Burghard.) The extension here is made in the long axis of the femur, which coincides with that of the upper fragment.

In the *treatment* of fractures of the shaft of the femur the surgeon should in all cases first satisfy himself that the blood supply of the injured parts is intact before he applies any permanent dressing. The chief difficulty which he will encounter is usually in connection with fractures of the upper third, for in these the tendency of the lower end of the upper fragment to tilt upward and outward is great and may be difficult to overcome, and, consequently, both shortening and deformity will happen in such cases. To prevent this, the best course is to treat the fracture by making extension as is shown in Fig. 78, and to employ, in conjunction with it, the metal splint (Fig. 79). In all fractures of the shaft, except those of the transverse, partial, or green-stick varieties, some shortening is inevitable; and if it does not exceed one inch, the treatment should be regarded as satisfactory. In fractures of the upper and middle thirds, I use the same

means as in fractures of the neck, viz., Buck's extension, with modified details, during the first ten days or two weeks, and then the plaster-of-Paris dressing applied in the ordinary manner. In some cases I have put up a simple and even a compound fracture in a plaster-of-Paris dressing from the very first; adopting the precaution, however, to provide at once a suitable fenestra over the seat of the fracture. If I find, in the subsequent progress of the case, that the

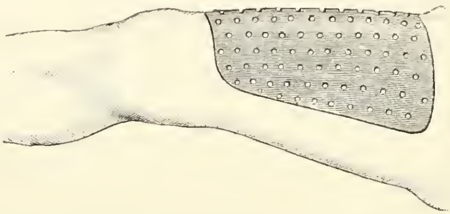


Fig. 79.—Metal Splint for Fracture of the Shaft of the Femur. (From Cheyne and Burghard.) This splint may usefully be employed to press down the upper fragment in place of, or in addition to, the plaster-of-Paris shield, which it closely resembles in shape. Extra weight can easily be added by moulding a sheet of lead outside the splint. This splint is used in addition to the weight extension.

extension in the horizontal position fails to correct the deformity (*e.g.*, in a fracture of the upper third), I then resort to the use of a Hodgen's splint or the old splint of Esmarch, or a double inclined plane (Fig. 80), or a single inclined plane with Buck's extension applied to the limb. Fractures of the shaft of the femur should be immobilized for six or eight weeks, and perhaps for a longer time, due consideration being given to the severity of the injury and the physi-

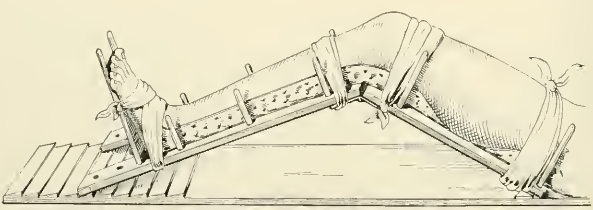


Fig. 80.—Esmarch's Double-inclined Plane.

cal condition of the patient. In fractures of the shaft in children, the same principles apply as in fractures of the neck of the bone in these patients.

In fractures of the lower third of the femur not recognized as belonging to those classed as "Fractures of the Lower Extremity of the Femur," the same methods of practice hold as for those of the "upper and middle thirds" of the bone, except when, for special reason, some change in treatment is required.

III. Fractures of the Lower Extremity of the Femur.

Fractures of the lower extremity of the femur may be produced by indirect force, but are mostly the result of direct force. The following varieties are of not infrequent occurrence: Supracondyloid fractures; fractures between the condyles; longitudinal splitting of the bone; separation of the epiphysis; and extensive comminution of the bone from severe crushing and gunshot injuries. (Fig. 81.) In the supracondyloid variety the line of fracture runs well above the epiphyseal line, in a slightly oblique direction downward and forward. The upper fragment is displaced forward and the lower backward, the three calf muscles aiding (by tilting) in increasing the deformity backward, while the hamstring muscles and the rectus pull the lower fragment and leg upward. The lower fragment may injure the large blood-vessels and nerves in the popliteal space. The patella is made prominent by the flexion of the joint in this backward displacement of the lower fragment, and at the same time there is a depression above the partially flexed joint. The late Dr. Gross stated that "the upper fragment may descend so far down as to push the patella away from the trochlea of the femur, over the tibia, so as to create the appearance simulative of partial luxation of this little bone." The supracondyloid fracture may be combined with a longitudinal splitting of the shaft, and is occasionally complicated with a vertical fracture that extends into the joint and separates the condyles. (Fig. 81.) Intercondyloid fracture is a serious condition, especially when a bad fracture is complicated with invasion of the large joint. In a supracondyloid fracture, there is widening of the joint, the condyles sometimes being separated by penetration of the shaft. Blood and serum distend the capsule of the joint, abnormal mobility is marked, and crepitus is present. These symptoms, together with those obtained by careful palpation, readily afford a diagnosis. The cause of such an injury is usually a fall upon the feet or knees, also blows inflicted directly upon the condyle. The knee is flattened and broadened, the fragment is drawn upward, there is crepitus, and considerable swelling will follow, but usually there is not much shortening. The late Dr. Gross also said that "fracture of both condyles may simulate a partial luxation of the tibia backward."

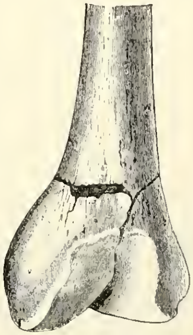


Fig. 81.—T-shaped Fracture of the Condyles of the Femur, caused by a fall upon the knee. (Von Bruns.)

The *treatment* of fracture of the lower extremity of the femur, if the joint is involved, will require, in the first place, measures directed to subduing the inflammation in and about the joint, the limb being kept, in the mean time,

in the position that will best aid, at a later date, in effecting coaptation of the fragments. Immobilization in supracondyloid injuries may be accomplished by means of the plaster-of-Paris dressing. At the end of six weeks this dressing should be removed, and passive motion and massage should be begun, with the use of douches and swathes of hot water. Da Costa, when he fails to accomplish reduction by horizontal extension, makes traction on the leg, at the same time gradually bringing it to a right angle with the thigh when it is suitably mobilized; he uses the double inclined plane and begins massage at the end of five weeks, restoring the limb, on each such occasion, to the splint after the movements are completed. He follows this course for three weeks longer and then dispenses with the splint, but continues the movements and massage until all stiffness has subsided. Da Costa uses this measure in treating a separation of either condyle. In longitudinal fractures in which the end of the bone is split, Da Costa uses the straight position in plaster of Paris for eight weeks. I have relied mainly on the plaster dressing in these fractures of the lower end of the bone, keeping up the immobilization for from six to eight weeks, and perhaps a longer time, according to the special indications of the cases, always beginning passive movements and massage just as soon as the degree of union will permit. Also I have been careful to warn the patient against the making of unusual movements in walking, and not to walk without the aid of a crutch and a stick or a pair of crutches.

Epiphyseal fractures do not occur after the twenty-first year of age, the symptoms resembling those of a transverse fracture above the condyles. The lower fragment is tilted to the front, while the end of the upper projects back into the popliteal space. Crepitus is softer than the bony kind. Reduction may be effected by means of extension and manipulation, and union secured by immobilization with a well-padded posterior splint and a plaster-of-Paris dressing.

I wish to reiterate the injunction to look well to the blood supply of the limb below the point of injury, more especially in *all* fractures of the lower extremity.

Fractures of the Patella.

Recent Fractures.

Fractures of the patella represent two per cent of all fractures, and they therefore constitute a common accident. The superficial location of the bone, with its special function and strong muscular attachments, will help to explain this frequency. The patella is essentially a sesamoid bone developed in the tendon of the quadriceps extensor muscle.

The causes of its fracture are muscular contraction and direct force, either

of which may act separately or both may act together. Muscular action usually produces a transverse fracture (Fig. 82), but in very rare instances the line of the fracture runs in a vertical direction, owing in part, it is thought, to the fact that the vasti muscles, because of their peculiar relations to the lateral aspects of the knee-cap, pull upon it in opposite directions when the leg is flexed.

Fig. 82.—Transverse Fracture of the Patella. (H. Rieffel, in Le Dentu et Delbet "Traité de Chirurgie.")

The bone is less frequently broken by direct violence than by muscular contraction. Direct violence produces various forms of fracture, the oblique, vertical, and star-shaped lines being the most common.

As just before stated, external violence and muscular contraction often coöperate in the causation of this fracture. Either of these causes may operate primarily, or they may be simultaneous in their action. In the latter case it is impossible to predict in which direction the line of fracture will run. The patella is more often fractured by muscular action than any other bone, but this cause is uncommon in early life. Hamilton reported a case in a boy five years of age. This fracture is an injury of active manhood and middle life, and occurs most frequently during cold weather, when the icy footways make falls more numerous. The act of resisting the fall, under these circumstances, causes sudden contraction of the quadriceps extensor, and, if the knee is flexed at the moment of this contraction, the patella is likely to be fractured. Both patellæ may be fractured at the same time. The joint, as well as the pre-patellar bursa, may be opened. Fracture of the patella occurs more often in the male than in the female.

The fracture may be located in any part of the bone, but is more frequent at or near its middle. It is quite often observed just below the middle, in the transverse furrow that exists on the front part of the patella. The apex of the bone may be the seat of fracture. A fracture may be partly transverse and partly oblique. The separation, in comminuted fractures, may run in various directions. Incomplete fractures are hard to detect, for abnormal mobility and crepitus will be absent. There is no doubt, however, that such incomplete fractures sometimes do occur. In fractures of the patella the adjacent soft tissues are more or less lacerated; the anterior fibro-periosteal layer is torn and stretched and often drops between the fragments, thus preventing approximation and interfering with union. The lateral expansion of the capsule is extensively lacerated. In cases of compound fracture the severe manner in which the tissues are injured, coupled with the probable involvement of the joint, explains why serious results may follow.

Symptoms.—Quite often a sudden snap is felt or heard in the knee, and the patient falls and cannot get up with the aid of the injured limb. However, if assisted to his feet, he is sometimes able to stand or even to walk slowly if

the extremity can be kept straight. In the recumbent posture, in cases of complete fracture with extended rupture of the contiguous aponeurosis, the patient is unable to raise the limb from off the bed. Palpation reveals the fact that the fragments are movable and widely separated, and this latter condition may easily be seen unless the swelling is great. The separation is due to the contraction of the quadriceps-extensor muscle, and the gap between the fragments may measure an inch or more in breadth. The displacement, which is usually of the longitudinal type, gives rise to a transverse depression in which the finger can be placed, unless the fragments are held together by untorn tissues. The mobility of the fragments depends on the line of fracture. If it runs transversely there will be free motion of the fragments in opposite directions. As to crepitus, it is difficult or impossible to detect its existence on account of the enormous swelling, due to the effusion of blood and of synovial fluid and the presence of inflammatory products around the joint; principally, however, because of the separation of the fragments and the presence between them of fibro-periosteal tissue and blood-clot. And if, on this account, the fragments cannot be approximated, and therefore union does not take place, the degree of separation is likely to increase continuously, because, as pointed out by Stimson, there is progressive shortening of muscles and retraction of the associated ligamentous structures.

The diagnosis is easily made, as a rule, from the history of the injury, from the patient's subjective symptoms, and from the loss of function.

The prognosis is unfavorable for bony union, and the unfavorable outlook —to repeat—is due to the forced separation of the fragments dependent on the effusion of blood and the subsequent formation of blood-clots, on the interference caused by the torn ends of the fibro-periosteal tissue, and on the shortening of the quadriceps extensor muscle and the ligamentum patellæ. The union usually is ligamentous, and this ligamentous tissue admits of more or less stretching by early or continuous or severe use, thereby impairing the usefulness of the limb. Bony union is rarely secured by the non-operative plan of treatment.

The cases of bony union of the patella are, as a rule, those in which the fragments have been directly approximated, which can be best accomplished by open incision and suturing of the fragments and the fibrous tissues with organic or inorganic material.

Treatment.—If the case is one to which the surgeon is called early, before much swelling has occurred, he should first apply a flannel bandage from the toes to the hip, making as firm pressure as practicable over the knee; then, a well-padded posterior splint, elevation of the limb to an angle of about forty-five degrees, and the application of an ice-bag or an evaporating lotion over the knee are in order. This plan usually will prevent much of the effusion and swelling that would otherwise take place. More often the swelling is great when the

patient is first seen, preventing an approximation of the fragments, and in this event aspiration of the joint is practised with the idea of hastening approximation of the fragments by the prompt removal of opposing fluids. The tardy coagulation of blood may permit of this removal of a sufficient amount to be advantageous in the treatment and to hasten the final recovery. If suturing is to be done, then aspiration is superfluous.

When the swelling has been reduced, the selected plan of treatment should begin. The first and most important act is to reduce the fragments and secure them in proper place. Extension of the leg, elevation of the limb, and perhaps flexing of the body approximately to a sitting position, and the application of direct correcting pressure to the fragments will usually suffice for a satisfactory primary adjustment of them.

These indications have been met by the employment of various appliances, only a few of which can here receive consideration. Those who are interested in tracing the evolution of these appliances, from the cumbersome contrivances employed by Paulus Aegineta and Ambroise Paré to the more practical apparatus of the present, will find, in the *International Clinics* (Vol. III., 15th series, 1905), a most interesting and instructive article on the subject by Wright, of New York.

The late Dr. Paul F. Eve used, after the method of Purman, an ordinary harness ring of various sizes for the treatment of fractures of the patella. O'Reilly, of St. Louis, proposed a very ingenious modification of the ring, it being an oval or oblong ring, open at one end, and adjustable by means of a screw so as to fit all cases.

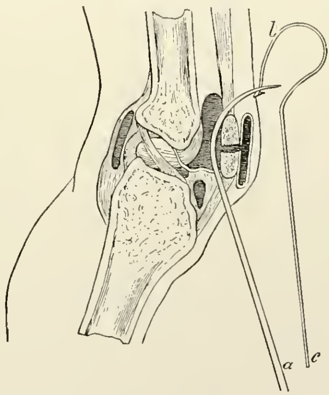


Fig. 83.—Shows Barker's Method of Holding the Fragments of a Fractured Patella together by Means of Silver Wire. The present figure shows how the curved needle (*a*), armed with the silver wire or a strong silk suture (*bc*), should be introduced behind the fragments. (Barker.)

Stimson, through a median longitudinal incision made down to the bone and exposing the attachments of the ligamentum patellæ and quadriceps tendon to the patella, and after removal of blood-clots from the joint and from the fractured borders of the bone and raising out of the way the fibro-periosteal shreds, joined the fragments together with a simple strong silk suture passed in succession close to the bone, transversely through the tendinous attachments just stated, and then, firmly tying together the opposing ends of the suture, completed the modified features of the plan.

Barker operated subcutaneously in the following manner: He made an in-

cision with a narrow-bladed knife down to and through the ligamentum patellæ at the point of insertion into the fragment, and another down to and through the like insertion of the quadriceps extensor, then carried through these incisions, from below upward beneath the patella, by means of a curved needle, a strong silk suture (Figs. 83, 84, and 85), the advancing end of which was then carried downward under the knee in the median line to the point of entrance.

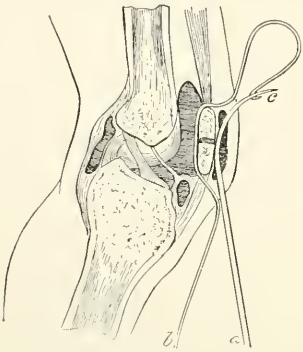


FIG. 84.—Shows the Second Step in Barker's Method. The wire is disengaged from the needle, and the latter is entirely withdrawn. Next, the needle is reintroduced, this time in front of the fragments, then re-armed with the end (c) of the wire, and finally again withdrawn. (Barker.)

The blood-clots on the fractured edges of the bones and any intervening fibrous tissue were displaced as much as possible by rubbing the fragments together, when the suture was firmly tied, the ends cut short, and the skin wound closed. Strong chromicized catgut may be employed instead.

"We agree with Stimson when he says that operative methods can be used with confidence when surrounded with every protection. He habitually uses them, but he never teaches them as proper routine practice, and strongly advises against their use except by those who have had experience, who have formed the habit of taking precautions, and who have the aid of skilled assistants. Operations should only be performed on healthy persons of suitable age, when the separation is over one-half an inch, or when there is much laceration of the capsule." (Da Costa: "Modern Surgery.")

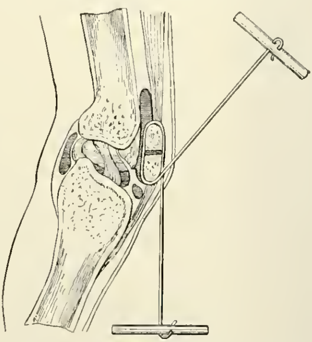


FIG. 85.—Shows how the Wire is to be Tightened in Order to Bring the Fragments together. The final step is the twisting of the ends of the wire after it has thus been tightened. (Barker.)

Scudder states: "The operation method consumes less time in convalescence, and an excellent result is achieved, but operation exposes to the danger of sepsis. It is the surest method of securing perfect apposition and bony union."

He describes the operation in the following terms: "The joint and the fractured bone are to be thoroughly exposed by a transverse incision. All clots should be thoroughly washed or sponged out. Any loose, small fragments of bone should be removed. In almost all cases a rather dense fascia will be

found overlapping the broken surfaces of the fragments (especially is this seen in a transverse fracture). These bits of overlapping tissue or curtains of tissue should be retracted and removed, or utilized in covering the sutured fragments. Whether silver wire is employed to suture the bone directly, or an absorbable material is used to suture the soft tissues, seems of little consequence as long as all fascial tears are sutured and the bony fragments are approximated. The weight of opinion to-day is in favor of absorbable sutures. Closure of the joint without drainage, and immobilization in the extended position, together with the treatment already mentioned, are indicated." (Scudder: "Treatment of Fractures," 1905.)

Preferring open incision and suturing of the fragments in many instances, I

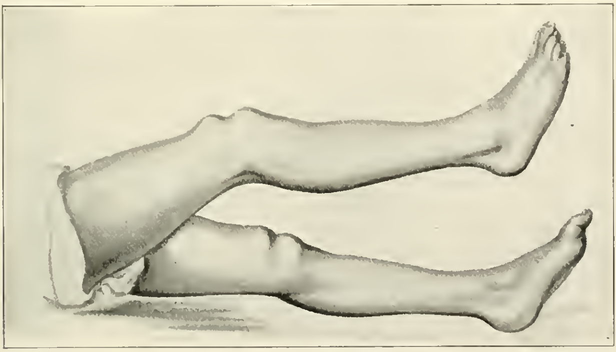


Fig. 86.—"A Young Man who Fell upon Both Knees and Fractured Both Patellæ Symmetrically. Eight weeks after the injury massage was begun, and the drawing shows that the patient was able, soon afterward, to raise one limb from the bed and maintain it in a position of almost full extension—this, despite the fact that the fragments were markedly separated. Nevertheless, as no further improvement was likely to take place, I performed on both knees the operation of suturing the fragments, and secured a favorable result." (Helferich.)

will briefly indicate my ideas regarding the general selection of cases, the preparations for and the essential technique of the procedure.

Those suffering from fracture of the patella, whose condition will permit, and whose environment will afford skilful treatment and care, need not hesitate to submit to operative practice when commensurate advantages appeal to the discretion of the patient or the surgeon. Operation should be deferred, if feasible, until after the acute symptoms of the primary injury have subsided, *i.e.*, from four or five days to a *week*. That in compound fractures of the bone operative treatment should be adopted appears to me to be self-evident. Also in instances of a crippled fellow-limb, of physical or business demands, of deteriorating personal discomfort, and of prospective activity of a perplexing nature, the wisdom of operation can well be considered. Prospective impair-

ments of function, of established importance (wide separation), and embarrassing delay of recovery, invite the consideration of active interference. I am opposed, however, to the policy and the practice of those surgeons who operate, for fracture of the patella, only because the bone is broken, and irrespective of the present dangers or the future benefits relating to the patient.

The preparation for operation includes all of those things which are generally recognized as essential to safe aseptic or antiseptic procedure at other parts of the body.

The primary incision may be made transversely just above or below the line of fracture; or of an oval shape with the convexity upward or downward, the latter being preferable; or vertically through the median line of the bone, as may best suit the fancy of the operator or meet the indications of the case. The transverse line of union of the soft parts is quite likely to be ruptured if refracture happens, especially when it is dependent on direct violence. Through this and the oval incisions, however, the joint can be the better cleansed and the ruptured capsule the more easily repaired than through the vertical incision. The joints should be cleansed by hot douching and careful wiping with small, soft, moist sponges. The finger should not be introduced into the joint unless it be covered with a rubber cot. The fibro-periosteal tissue often found dependent between the fragments should be raised upward and trimmed off, unless possessed of sufficient structural integrity to warrant the belief that by sewing it to the opposing tissues it will lend aid to bony union. From the broken edges of the bone the blood-clots should be scraped with an ordinary small, sharp-edged bone-spoon. The opposing bone borders should be bored through correspondingly with a small bone-drill, in such a manner as to permit of their accurate and close apposition, when the wire should be firmly twisted into place and the ends cut off and turned down and gently forced against the bone. One small wire at the median line is quite sufficient and should be passed in such a manner as not to invade the joint nor tear out when twisted into place. Small loose fragments should now be removed, and the fibro-periosteal tissue united with catgut suturing over the line of fracture if feasible. The portions of lacerated capsule at either side of the joint should then be repaired, if desired, by sewing with catgut, and, in doing so, care should be taken not to include an unnecessary amount of the torn fibres, as thus undue shortening of that structure will increase correspondingly the difficulty often attending the renewal of proper joint movements. In recognizing the fact that, in good recovery from fractures without open operation, fully serviceable joints are secured, notwithstanding non-surgical repair of the ruptured borders of the capsule, some surgeons are disposed to employ a short vertical primary incision and omit all effort to secure extended repair of the torn capsule. Drainage need not be employed unless for some reason the surgeon regards its presence

as salutary. In closing the wound of the superficial parts, special pains should be taken to cover the line of fracture as securely as possible with soft contiguous tissues, so that, if infective processes gain access from without or approach indirectly from within, a good protective barrier may have been already interposed against the farther advance. Any difficulty that may be encountered by the surgeon in this respect will, as a rule, be promptly surmounted by the exercise of ordinary forethought and practical expediency on his part. As a means of securing drainage, when it seems to be indicated, the following measures may be adopted: On either side of the joint, outside of the condyles, make an opening through the soft tissues by means of closed, sharp-pointed scissors curved on the flat; enlarge these incisions by opening the scissors and thus putting the tissues on the stretch; pass a curved and rather slender pair of forceps from within outward along the outer surface of the blades of the scissors; and, seizing a bunch of numerous strands of silkworm gut, doubled evenly on themselves, pull it into the joint cavity. Rubber tubing will not be efficient when thus introduced, because of the closure of the lumen by the pressure of the fibrous tissue through which the opening is made. The limb should be dressed in the usual manner, placed on a splint, and raised enough to relax the muscles inserted into the patella. When a drainage agent is employed, the part should be re-dressed on the third day, and the agent removed unless contra-indicated. At the end of the third or fourth week, and sometimes before in operative cases, if recovery has gone on uninterruptedly, a light posterior wooden splint may be applied, or the limb may be encased from the ankle to the perineum in a light plaster-of-Paris, felt, or sole-leather splint, care being taken to keep this splint firmly applied, and the patient using a cane or crutches. On frequent occasions during recovery in the open and closed methods of practice, the dressings should be renewed and bathing and massage of the limb performed. After this, apply a light posterior splint, suggestive of the necessity of care on the part of the patient in the use of the limb; or, better perhaps in some patients, a splint with an adjustable lock at the knee, permitting of limited, though increased, motion at intervals, should be utilized along with the support of a walking-stick. It is better, in my judgment, to secure the benefits of passive motion by means of the patient's sensitively guarded movements, with increasing range of mechanical control, than to make forcible flexion in the intervals of quiet. Such a course as the former encourages normal use of the limb without the danger of undue stretching of fibrous structures or of breaking up bony union. This line of after-treatment is suitable for the open or the closed methods of practice, provided, however, that in the latter the beginning and the ending of the treatment be somewhat longer deferred. It is far wiser, as it seems to me, that the patient's movements be guarded for a week or two longer than may appear to be necessary, than that a too exact timing of freedom from restraint result in a lengthened fibrous or a fractured

bony union. The fact that refracture usually takes place at the seat of union further emphasizes the need of care in this regard.

It is not always necessary and it may be inexpedient to suture the fragments with wire; instead, chromicized catgut, kangaroo tendon, etc., may be used, and, if preferred, the sutures need not pass through the bone, but may be carried through the fibrous tissues closely connected with the surface of the bone. At the same time, if thought advisable, borings may be made to receive these apposing agents. In comminuted fracture the attached fragments of bone should be apposed and held together preferably with organic agents, more especially when the fragments are too small to justify attempts at boring.

Blake, of New York, has modified the usual plan of procedure in fractures of the patella in an admirable manner, as it seems to me. After completion of

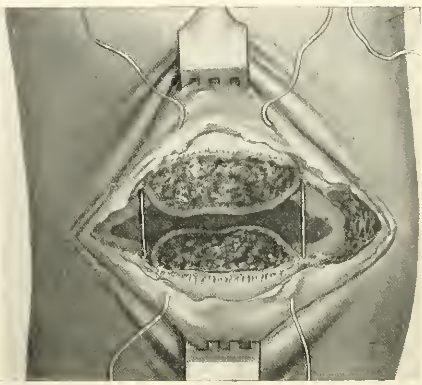


FIG. 87.—Shows How the First Sutures are Applied in Blake's Method of Treating Fractures of the Patella. (From Bryant's "Operative Surgery," D. Appleton & Co., New York.)

the usual operative steps for uniting the fragments, instead of suturing them, Blake sutures, at either side of the broken bone, as close as possible, with chromicized catgut or kangaroo tendon, the torn aponeurosis (Fig. 87) for a distance of half an inch or so. If the fragments be carefully adjusted before tightening the sutures they will afterward be found to be quite as immovably apposed as when joined together with wire. In other respects the technique (Fig. 88) is similar to that already stated. The operative advantages of the method would seem to be at once apparent.

It is natural, in a fracture of so much practical importance and heretofore burdened with oppressive and often painful treatment with imperfect results, that many diverse plans of treatment should have been suggested and tried, especially since the advent of asepsis. Of this number I will mention only the

method advocated by Schafer—a method not unlike that of Barker. It is thus described by its author:

"A short, preferably slightly curved trocar is pushed through the quadriceps tendon above the patella, and another one through the ligamentum patellæ below. The stylet is removed from each, and through each cannula a silver wire is threaded, the ends being united over a compress placed over the broken bone. In order to avoid interposition of the lacerated bits of fascia between the bone fragments, the skin and underlying soft parts are forcibly drawn upward and downward respectively by the operator and an assistant immediately before the trocars are introduced, while at the same time the bone fragments are approximated. The procedure can be carried out under local anæsthesia, and at the expiration of from five to eight days daily massage of the musculature can be

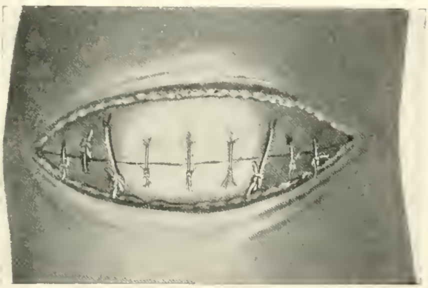


Fig. 88.—Shows the Location of the Two Sets of Sutures (Blake's Method) after They have been Tied and the Fragments of the Patella Reduced. (From Bryant's "Operative Surgery," D. Appleton & Co., New York.)

begun. With the beginning of the third week passive, and then active, movements are commenced, and the wires are removed at the end of from four to five weeks. The treatment is finished at the end of six or seven weeks."

The simplicity, safety, and effectiveness of the method are strongly emphasized by the author. It has, however, nothing special to commend it above that of Barker, by whose instrumental technique the former can be quite well explained.

Other methods of subcutaneous suturing of the fragments are known, but they offer no adequate advantages over those already explained to justify me in devoting further space to their description.

Old Fractures of the Patella.

In old fractures of the patella great care should be exercised in the application of remedial measures, else that which is already bad may be made decidedly worse. The conservative resources of nature, supplemented by the outcome of training and of the intuitive control exercised by the patient over

a disabled member, contribute in a wonderful degree to the attainment of practical functional use in old fractures of the patella. Nearly every surgeon has, time and again, been invited to undertake the repair in instances of old and wide separation of the fragments, attended with disabled yet astonishing use of the limb. And, doubtless, not all who were consulted—to say nothing of the patients themselves—have been satisfied with the outcome.

For the purpose of joining together the fragments in these cases, division of the quadriceps tendon, of the rectus and vasti muscles, so fashioned as to cause their increased lengthening when their divided borders are united by sutures, has been practised. Also, lengthening of the ligamentum patellæ by plastic method and transplantation of the point of insertion to a higher plane, to meet a similar indication, are measures that are not strange to the surgeon.

Fractures of the patella, when treated by the most approved means, do not always unite. The inability properly to approximate the fragments; the occurrence of septic conditions and of necrosis; the presence of diathetic states, of deficient blood supply from old age, or of disease (old fracture)—each one of these not infrequently exercises a determining influence on repair.

In very many simple fractures of the patella one will be content to use at first a well-padded posterior splint, pulling the fragments into position with strips of adhesive plaster and holding them with a properly fitted harness ring or plaster-of-Paris dressing for the first weeks; after which time Bryant's or von Bruns' ambulatory dressing (Fig. 103) and crutches or a cane may be utilized for five or six weeks, as may be thought best. Some authorities advise that, after the splints have been removed, a lacing knee-cap of leather should be worn in the daytime for one year. This seems to be unnecessary, at least for such a length of time.

The Results.—In the closed method a serviceable limb is the outcome when reasonable care is exercised, irrespective of the plan of treatment pursued. In the open method, with suitable aseptic care, a favorable result, with complete restoration of function, can be confidently expected.

Powers, in 1898 (Transactions of the American Surgical Association), reported 711 cases, 474 of which were from personal communications and 237 from the literature of the two preceding years. Of the first series, 4 died; of the second, 6 died. Of the total (10), 3 died from sepsis, and the remainder from causes not related to operative technique.

Fractures of the Leg.

Fractures of the leg constitute, according to Stimson, six per cent of all fractures, and one-fourth of those of the lower extremity; von Bruns, on the other hand, places the frequency at sixteen per cent of all fractures. The most frequent site is at the junction of the middle with the lower third of the leg.

Many of these injuries are due to direct violence; and in this connection it should be remembered that a large portion of the anterior surface of these bones is superficial, and consequently that a lesion of the soft tissues is extremely liable to occur from the violence which produces the fracture. When the injury has been caused by muscular action or by an indirect force, the sharp ends of the bony fragments are likely to puncture or lacerate the soft parts, which is especially true in those cases in which the limb is subjected to a twisting force. Finally, osseous tissue constitutes such a preponderating part of the leg, and especially of its anterior aspect, that a large number even of gunshot wounds of the leg involve one or both bones.

While these fractures may occur at any age, they are found in greatest frequency in the decades between thirty and sixty, about equally in each decade, and possibly more often in males.

In considering these fractures we will divide them into: (1) Fractures of the Tibia; (2) Fractures of the Fibula; and (3) Fractures of both Tibia and Fibula.

(1) *Fractures of the Tibia.*

Fractures of the tibia are subdivided into: (*a*) Fractures of the Upper End; (*b*) Separation of the Upper Epiphysis; (*c*) Avulsion of the Tubercle; (*d*) Fractures of the Shaft; and (*e*) Separation of the Lower Epiphysis.

(*a*) *Fractures of the upper end of the tibia* may be caused either by direct or by indirect violence. The kick of a horse and the impact of a heavy or rapidly moving body are examples of the former; and a fall from a height on the feet, or a twist of the limb, causing either abduction or adduction, are examples of the latter. The line of fracture may be transverse, oblique, or longitudinal, and may involve the articulation.

In a transverse fracture the symptoms are pain, mobility, crepitus, and displacement. The displacement, however, may not be marked, although there will be some evidences of contusion over the fracture. If the fracture occurs high up near the articular surface, care must be exercised not to mistake the lesion for a dislocation of the knee; and an anæsthetic or the Roentgen rays may be needed for discriminating between the two. In an oblique fracture the displacement is marked, and consequently the irregularity of outline, together with the other signs of fracture, will render a diagnosis easy.

If the fracture involves the knee joint the injury must be looked upon as a serious affair. The existence of an inflammatory process near so large an articulation, the involvement of the articular surfaces in oblique and comminuted fractures, and the length of time required for repair of the bone, amounting sometimes to three or four months, demand a guarded prognosis. Although in comminuted fractures a satisfactory union can be obtained, stiffness of the joint may ensue. "Both tibial arteries and the popliteal vein,"

says Stimson, "have been torn in this fracture," and these are injuries which may cause loss of the limb, if not of the patient's life.

Treatment.—After reduction has been effected by extension and manipulation, the limb may be immobilized in either the straight, the extended, or the flexed position. If the limb has been placed in the straight position, the plaster-of-Paris dressing, extending from the foot up on to the perineum, and re-enforced, if need be, by gutta-percha or a metal strip placed beneath the seat of the fracture, will suffice; but this dressing should not be applied until inflammatory action is controlled. As a substitute for plaster of Paris a thin piece of pine board of proper width and padded so as to fit accurately the posterior surface of the thigh, popliteal space, and calf of the leg, may be employed.

In exceptional cases extension by means of weight and pulley may be needed to draw down and hold the leg in proper position. The anterior splint of Smith or of Hodgen or the double-inclined plane has been used satisfactorily by those who prefer the flexed position. A plaster-of-Paris splint thoroughly applied and swung may meet all indications. For the removal of blood or serous effusion that may be present in the joint, aspiration may be required; and in compound injuries, if suppuration is detected, it will be better to make lateral incisions, low down, than to depend on the wound for drainage. If improperly reduced fragments should lock the joint, it will be necessary to remove them by incision. The essentials of asepsis and antisepsis are as imperative here as in compound fractures of the patella.

The immobilizing apparatus must be removed occasionally after the first two weeks in simple fractures, and as soon as possible in compound, so that passive motion and massage may, if possible, be fully utilized in securing a serviceable articulation. But the results which I have obtained with a plaster-of-Paris dressing have been so satisfactory, and the dressing itself has been so comfortable to the patients, that I give it the preference.

(*b*) *Separation of the upper epiphysis* has been observed in a few instances in persons under twenty years of age, and is due to a sudden twist of the leg, either in abduction or in adduction; although Poland, in his monograph on "Traumatic Separation of the Epiphyses," says that direct pressure against the epiphysis is a more common cause than the indirect above mentioned. In nearly all cases the tubercle is also torn away.

The displacement, if any, is slight, is commonly perceptible, and may be either forward, forward and outward, or laterally. In some cases the diaphysis is also more or less extensively broken.

(*ab*) *Avulsion of the tubercle* has sometimes been caused by an unusual strain transmitted through the patella from contraction of the extensor muscles. This rarely occurs after the eighteenth year of age, and is most often caused by jumping. The cartilaginous union of the tubercle with the epiphysis does not undergo thorough consolidation until full growth is attained. The lesion

is indicated by the snap which occurs at the time. About two inches below the patella a bony mass, movable and painful, can be felt, and when it is pushed downward and backward crepitus can be distinguished. The power of extending the leg is seriously impaired or entirely lost. This injury may be mistaken for rupture of the ligamentum patellæ, or even for fracture of that bone, especially in instances of severe complicating injury.

Treatment.—The leg being in the extended position, push the fragment into place; then apply a popliteal splint and allow it to remain until all inflammatory action in and about the joint shall have subsided. At this time a plaster-of-Paris bandage should be applied from the foot to near the perineum; it should be lighter below, but heavier above and over the seat of the injury. Strips of adhesive plaster will aid in maintaining apposition. Either the popliteal splint or the plaster-of-Paris bandage may be used exclusively, but, whichever it may be, it should be removed about the fourth week.

Incision of the overlying soft parts, and drilling a hole through the tubercle and underlying bone and pegging them together with a bone or ivory peg, have been resorted to successfully in securing a union of the fragments. A good result may be expected in these injuries, but perfect restoration of function may be delayed for a long time.

(c) *Fracture of the shaft of the tibia* at any point may be due to direct violence, but at the most frequent site of fracture—viz., the juncture of the middle and lower thirds—indirect force is the most frequent causative factor. Twisting of the limb by a sudden and forcible contraction of the muscles of the leg is an important factor in fractures at the lower part of the shaft. A fracture at the upper part of the shaft is usually transverse, but in the lower part, as a rule, it is oblique, and may be spiral or V-shaped; in the latter case the upper fragment terminates in a sharp point, triangular in shape, and situated in front and to the inner side of the bone, while the lower fragment shows a seam or split that may extend down into the ankle joint. Injury to the vessels may occur, and it should be carefully looked for, and any bleeding that may be present should be controlled at once.

The symptoms are pain, loss of function, mobility, crepitus, and deformity. This last symptom, owing to the superficial nature of the tibia at its anterior surface, and to the mobility of the fragments, will be readily perceptible. If both bones are broken, the mobility will be greater, and the fracture of the fibula can usually be detected by running the finger along its anterior aspect. A contused artery may exhibit hemorrhage at any time within a week or ten days following the accident.

A simple fracture here, in a person of good systemic condition, should become consolidated in six weeks, but a compound or extensively comminuted fracture or one involving the ankle joint may require double or treble that length of time before recovery takes place. Suppuration in a compound injury greatly

delays repair, and may induce necrosis or cause the establishment of sinuses which lead down to diseased bone, and which may close and reopen intermittently unless properly treated.

(*d*) *Fracture of the Internal Malleolus.*—Direct traction on the internal lateral ligament, by sudden out-turning of the foot, may break off the internal malleolus. There will be pain, mobility, loss of function, and displacement of the lower fragment downward, with a depression between the fragments.

Treatment.—In some cases we apply the plaster of Paris at once; in others we employ preliminary treatment for the purpose of reducing swelling and controlling inflammatory action, while at the same time endeavoring to maintain apposition of the soft parts and bony fragments by any convenient means of immobilization. In fractures situated lower down it is usual to employ side splints, a fracture box, a posterior gutter splint, a Syme's anterior splint for the leg and ankle, or an improvised anterior angled splint made by joining two pieces of thin board together at such an angle as will fit the anterior surface of the leg and upper part of the foot, or any form of mechanical device that will maintain apposition and immobility until the limb can be encased in plaster of Paris. The permanent dressing may be removed at the end of five or six weeks, and the patient allowed to walk at first with crutches, or with a crutch and a stick. For the first two or three weeks he should walk only in this manner, using the injured limb as little as possible. Afterward he may discard first the crutch and later the cane or stick. In effecting and maintaining reduction the foot can be used to control the lower fragment.

(*e*) *Separation of the Lower Epiphysis.*—Separation of the lower epiphysis is rare, but more common than separation of the upper one. The symptoms are: mobility, soft crepitus, and the other usual signs of fracture; and the diagnosis, in which the patient's age plays an important part, is usually not difficult. The treatment consists in reducing the displacement and immobilizing the limb with plaster of Paris, which should be cut up before hardening, and occasionally tightened as the limb shrinks. Four or five weeks will usually suffice for union.

(2) *Fractures of the Fibula.*

Fractures of the fibula are more common than those of the tibia; the reasons for this being that the fibula is much lighter than the tibia in proportion to length, and that its position on the outside of the leg exposes it more to injuries; also outward turning of the foot frequently fractures it. Fractures occur much less frequently in the upper two thirds of the bone than in the lower third, and they are usually due to a direct force in the former locality, and to an indirect one in the latter. In the upper two thirds the bone is so deeply embedded in the muscles that it is not easy to detect a fracture, and, besides, in many cases the patient can walk, notwithstanding the fracture, al-

though he will have some pain at the seat of the injury. The normal elasticity of the bone is liable to be mistaken for abnormal mobility, but pressure on the lower fragment will not disturb the upper. Crepitus cannot always be elicited, but the x-ray will readily afford correct information. "A linear ecchymosis," says Da Costa, "may appear later in the history of the case."

Fig. 89.—Pott's Fracture. (Massachusetts General Hospital.)

Immobilization for four or five weeks with plaster of Paris will generally suffice to secure union.

Fracture at the lower third is far more common, and it has received the name of "*Pott's fracture*" (Fig. 89). As a rule, it is due to an indirect force. Stimson places great stress upon abduction and eversion of the foot in the production of this fracture. He claims that eversion of the foot gives a square break at the base of the internal malleolus, the tibio-fibular ligament being ruptured or there being avulsion of that portion of the tibia to which it is attached, and the fibula breaking close above the external malleolus by pressure on this process. Abduction, he says, causes an oblique fracture of the fibula two or three inches above the malleolus, the margin of the internal malleolus giving way obliquely, with rupture of the anterior portion of the internal lateral ligament first, and subsequently of the tibio-fibular ligament. In a case recently coming under my observation, the patient, while walking on uneven ice, slipped and fell, breaking his left fibula, as sometimes occurs with inversion of the foot, especially in the presence of sudden and forcible violence.

Von Bergmann says, in connection with Pott's fracture: "All these injuries are produced by twisting the foot upon uneven ground, or by falling sideways while the foot is fixed, for example in a hole, a railroad track, or between rocks, or by violent rotation of the leg while the foot is fixed, or by the foot being everted or inverted forcibly against the ground in jumping or falling." In fracture by inversion or adduction, he says: "If, while the foot is fixed, the body falls to the tibial side, or if the foot is twisted inward by a misstep or in jumping, or if, while the leg is fixed, the foot is driven violently inward and upward, the tibio-fibular and external lateral ligaments are put

upon the stretch and the latter tears the external malleolus off at its point of insertion if it is stronger than the bone; the result is a transverse or slightly oblique fracture about three-eighths of an inch above the tip of the malleolus. If the force is continued, the astragalus is driven inward against the internal malleolus and breaks it partly or completely off; if the fragment is displaced the foot stands in the varus position." (von Bergmann, "System of Practical Surgery," edited by Bull.)

The same authority, in speaking of fractures by eversion and abduction, says (p. 465 of Vol. IV. of the original German edition) that they "are much more frequent than the above, and are produced similarly, but in the opposite direction, by violent eversion or abduction of the foot. If, for example, the entire foot is held firmly while the body falls outward, the deltoid ligament is put on the stretch; it is rarely torn, but usually tears off the internal malleolus, and as a rule near its base; exceptionally the ligament is torn off at its insertion on the astragalus. . . . The fibula breaks at its weakest point above the

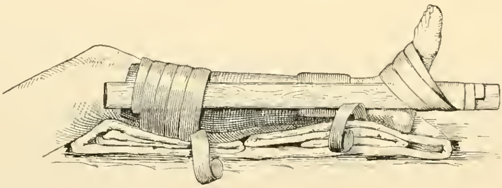


Fig. 90.—Dupuytren's Apparatus for Use in Treating Fractures of the Leg.

tibio-fibular ligaments, namely, two to two and one-fourth inches from the tip." This, he says, is typical Pott's fracture.

Symptoms.—These often vary materially, owing to the peculiarities of each case. As a rule, there is limited or marked eversion, and nearly all measures of treatment look to securing recovery without eversion of the foot. Only in rarely exceptional instances is there inversion, which, however, is readily corrected. Occasionally the foot is markedly everted, from excessive spasm of the gastrocnemius causing tension of the tendo Achillis, with deformity and a backward displacement of the foot. When the foot is everted, there is depression at the site of injury, slightly changing the contour of the ankle. The latter change, however, will be more marked if the internal malleolus, or the tibia just above the joint, is fractured. In some cases the foot may be abducted so as to present the appearance of a dislocation of the ankle; in other cases the malleoli are farther apart than in the uninjured limb, the foot is too freely movable laterally, and crepitus can usually be elicited. The everted foot can easily be brought to its proper position in the majority of instances, but, when released, it at once resumes the previous deformity. Palpation discloses the fact that, as a rule, the upper end of the lower fragment underlies

the upper fragment and points toward the tibia, or leans inward and slightly backward, especially in the instances of decided deformity. Stimson mentions three points where pain or at least tenderness on pressure is quite a characteristic feature, viz., on the fibula at the seat of fracture, in front of the tibio-fibular ligament, and at the anterior border of the internal malleolus.

Treatment.—In a simple fracture at the lower end of the fibula, a permanent dressing of plaster of Paris generally suffices. In some of the cases of compound or comminuted fracture, or in cases attended with marked inflammatory features characterized by great swelling of the tissues, or with effusion into the joint, it may be necessary to apply a temporary dressing, such as Dupuytren's splint (Fig. 90) or another of similar utility. This splint is made of a straight piece of thin board reaching from the middle of the thigh to just below the

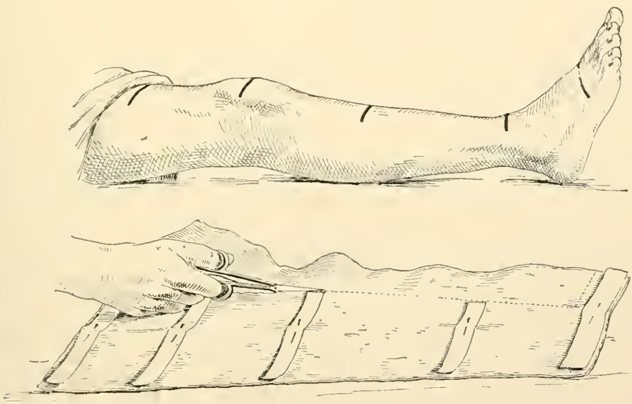


Fig. 91.—Croft's Splint; Method of Cutting out the Lateral Portions. (From Cheyne and Burghard.) The pieces of white paper in the lower figure are equal to half the circumference of the limb in the upper at the corresponding marks, with the exception of the right-hand one, which is equal to the distance from the point of the heel to the mark at the root of the toes.

foot, and is padded with a long wedge-shaped pad, with the thick end placed along the inner surface of the leg, beginning just below the internal malleolus, while the thin end reaches nearly up to the upper end of the splint. The splint itself may be secured by three strips of adhesive plaster, or by webbing with buckles, or by turns of a plain roller bandage, one of which, according to Da Costa, should be passed just above the ankle, another just below the head of the fibula, and a third at the upper end of the splint; or it may be secured by a few turns of a roller bandage at the upper end and a figure-of-8 around the ball of the foot and ankle. This arrangement permits of ready observation, so that one can see if proper apposition is being maintained. Other forms of splints have also given satisfaction. Such, for example, are a fracture box, care being taken to protect the heel

by padding placed above, but *never* beneath it; a suspended wire splint; or a plaster-of-Paris dressing. Of these splints I prefer the last, which should either be applied from the beginning or after a Dupuytren's splint has been worn for a certain length of time. The padding at the lower end should be thick enough to admit of adequate inversion of the foot without bringing it into contact with the splint.

(3) *Fractures of Both Tibia and Fibula at the Same Time.*

Fractures of both bones of the leg at the same time are quite frequent, and are very often compound, sometimes comminuted. Fractures of the upper part of the leg are due to direct violence; fractures of the lower part are due to indirect violence. When a fracture occurs in the lower part, the tibia usually breaks first, and the fibula later and at a higher point. While fractures of the upper part are mostly transverse, in the lower part they are oblique, spiral, V-shaped, etc.

A comminuted fracture is far more readily recognized than a single fracture of either bone. The greater mobility, the crepitus, the displacement, the deformity, and the functional disability render the diagnosis in these instances

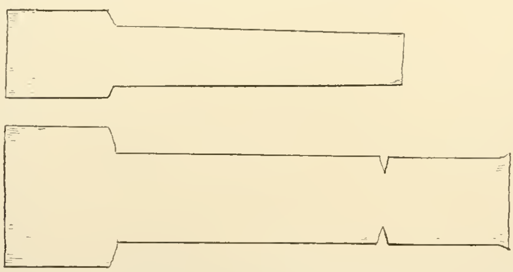


Fig. 92.—Croft's Splint. Shape of the Anterior and Posterior Portions. (From Cheyne and Burghard.) The upper one is the narrower anterior piece. The relative width of the two portions can be varied at will to suit the needs of any particular case.

comparatively easy. Some difficulty, however, may be experienced in those cases in which there is a complete fracture of one bone, while the other is the seat of a partial or green-stick fracture. Pott's fractures may properly find a place in this class, although they were considered in connection with fractures of the fibula, owing to the fact that the lesion in this bone is greater than that in the tibia, and is in some cases limited to it.

Treatment.—The principal feature of the treatment is the plaster-of-Paris dressing which has already been sufficiently described in the sections relating to fractures of the tibia and fibula, and consequently will not be considered again. Croft's splints, which may be found useful in the treatment of these cases, are shown in the accompanying illustrations (Figs. 91–97). The

fracture may be complicated by a backward dislocation of the foot, and special measures may be required for the relief of this complication; or the tendo Achillis may require subcutaneous section, which should be resorted to in cases in which contraction of this tendon occasions much displacement or difficulty in securing and maintaining proper reduction.

In severe cases of fracture of the leg, with great destruction of bone and soft tissues, or with injury to the large vessels, the injury should be *most carefully investigated*, and if the outlook for the recovery with a useful limb seems

FIG. 93.—Croft's Splint. Removing the Excess of Plaster from the Lateral Portions. (From Cheyne and Burghard.) This shows a simple way of insuring an even distribution of the plaster.

to be doubtful, and more especially if the attempt involves danger to the patient's life, the question of amputation, as soon as shock has passed away, should be seriously considered. In these days of highly perfected prosthetic appliances the loss of a foot or a leg is not so serious a deprivation as in olden times. In the decision of a question of this nature, the exercise of conservatism is most earnestly urged.

Compound fractures of the tibia and fibula are usually a source of great

anxiety, not only on account of their serious character, but also because Nature's efforts at repair do not seem to be as effective in injuries of the leg as in injuries of some other parts of the body. As regards the treatment of compound fractures Morse very properly says:

The modern antiseptic treatment must vary according to the nature of the wound and the manner in which it was inflicted. As a general rule, it may be stated that

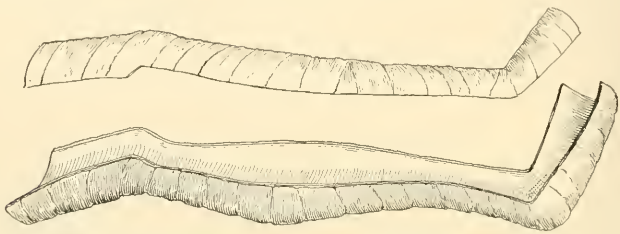


Fig. 94.—Croft's Splint. The Antero-posterior Splint Removed. (From Cheyne and Burghard.) The figure shows the trough-like splint thus formed.

the first dressing decides the fate of the patient and determines the process of wound-healing. The treatment of the wound is of far greater importance than that of the fracture itself, more especially during the first two weeks. A combination of most thorough antiseptic treatment of the former, immediate and perfect reduction of the latter, and subsequently fixation of the fractured limb by some kind of plastic splint, yields the best results. Whenever there is any prospect of obtaining primary

Fig. 95.—Croft's Splint. Application of the Anterior and Posterior Portions. (From Cheyne and Burghard.) The illustration shows the interval down the side of the limb between the two portions.

healing of the wound, the attempt to secure it should be most faithfully made. In punctured and gunshot fractures and when the wound is small and clean-cut, the surrounding skin for a distance of several inches should be shaved and thoroughly disinfected by scrubbing with hot water and potash soap, then with alcohol, and lastly with a five-per-cent carbolic-acid or a 1:1000 mercuric-chloride solution. If the bone projects from the wound, the part protruding should be included in the disinfection

before reduction is made, as otherwise infection may be caused by the reduction. Such fractures must never be explored, and the wound should not be enlarged unless reduction is impossible without so doing or complications present themselves that demand it. Resection of the projecting fragment is seldom necessary, as reduction can usually be effected under an anæsthetic. It is in cases of this kind and in gun-

Fig. 96.—Croft's Splint. Bandaging on the Lateral Portions. (From Cheyne and Burghard.) The surgeon holds the fracture in a good position and the foot at right angles, an assistant keeps the lateral portions in position at their upper end, while a second assistant applies the muslin bandage.

shot fractures that, as a rule, the wound beneath the skin is aseptic. Suturing of such wounds should be avoided.

The wound, properly disinfected, is dressed by applying an antiseptic occlusion dressing. For this purpose nothing is more efficient than a non-irritating antiseptic powder, composed of four parts of boric acid to one part of salicylic acid, and a compress of aseptic absorbent cotton. Cotton is preferable to gauze, as it serves as a more efficient filter, and with the powder and blood is soon converted into a dry crust that seals the wound hermetically and excludes it from the entrance of pathogenic

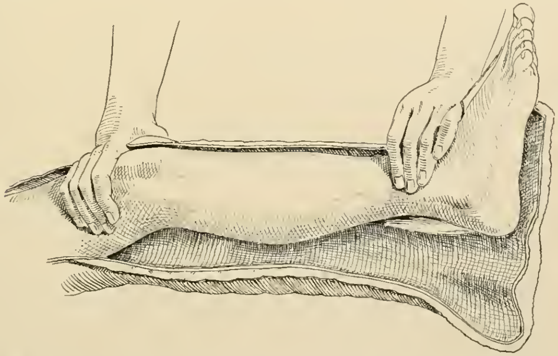


Fig. 97.—Method of Examining a Limb in a Croft's Splint. (From Cheyne and Burghard.) The limb is held steady in one half of the splint while the other is opened out.

microbes. About a teaspoonful of the boro-salicylic powder is placed on the wound, and the cotton compress is applied and retained with a gauze roller, or, if there is any danger of it becoming displaced, it is fastened in position with a strip of adhesive plaster before the bandage is applied. The dressing should not be disturbed until the wound is healed, unless signs and symptoms indicate the existence of

infection. Should infection follow this treatment, removal of the dressing, enlargement of the wound, counter-openings, efficient tubular drainage, energetic secondary disinfection, and substitution of the hot antiseptic compress for the dry dressing constitute the proper course to pursue. If wound infection does not occur, the compound fracture is converted at once into a simple subcutaneous fracture, and should be treated as such.

P. Bruns recommends for similar cases a powder composed of

Carbolic acid	25 parts
Colophonium	60 "
Stearin	13 "
Precipitated carbonate of lime	700 "

Senn says: "I have, however, used the boro-salicylic powder, in the proportion specified, on an extensive scale, both in civil and in military practice, and have been so much gratified with the results that I can recommend it most emphatically as a local application in such cases, used in the manner described."

The after-treatment of a compound fracture by the surgeon [says Dr. Morse] cannot be too carefully watched. He must, day after day, look for evidences of infection. A rise in temperature during the first twenty-four hours usually means ferment in-

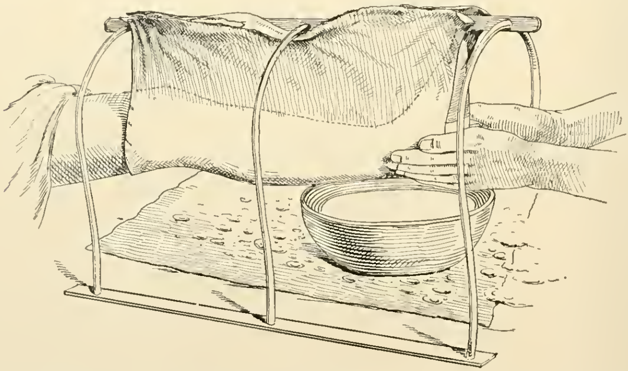


Fig. 98.—Bavarian Splint. Method of Application. (From Cheyne and Burghard.) The inner layer of flannel is being smeared with liquid plaster-of-Paris. The outer layer is seen beneath the basin and is ready for application to the plastered surface.

toxication; after that time it suggests septic infection. In fermentation fever the subjective symptoms are generally *nil;* in sepsis they correspond in intensity with the degree of intoxication. The condition of the tongue is of more diagnostic importance than the character and frequency of the pulse in discriminating between fever and sepsis. In septicæmia the tongue is dry and usually brown; in fermentation fever it is moist and coated. If, from the local and general symptoms, it becomes apparent that the wound has become infected, no time must be lost in removing the dressing and making additional provision for drainage. Secondary disinfection is generally incomplete and unsatisfactory. If the wound has been sutured, every stitch must be removed and drainage established wherever it appears

necessary. A moist antiseptic compress must take the place of the dry dressing, and frequent antiseptic flushings become indispensable. It is advisable, under such circumstances, to replace the more energetic antiseptic solutions, such as carbolic-acid and mercuric-chloride, by Thiersch's solution or a saturated solution of the acetate of aluminum, as the former, used in large quantities and at short intervals, might, and often do, result in intoxication that may prove disastrous and even fatal.

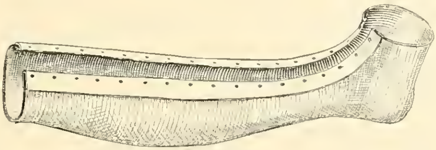


Fig. 99.—Bavarian Splint. (From Cheyne and Burghard.) The splint has been removed from the limb and finished by binding the edges with leather and punching eyelet holes in it.

The *antiseptic irrigation* should be preceded by the injection of hydrogen dioxide. If suppuration does not yield promptly to this treatment, continuous irrigation with either of the mild antiseptic solutions must be instituted at once, and has often, in my experience, been the means of averting death from sepsis and in preventing the necessity of a secondary amputation. Should this treatment not make a prompt impression by improving the local condition and by ameliorating the general symptoms, the propriety of performing a secondary amputation must be considered, with a view to preventing death from septico-pyæmia.

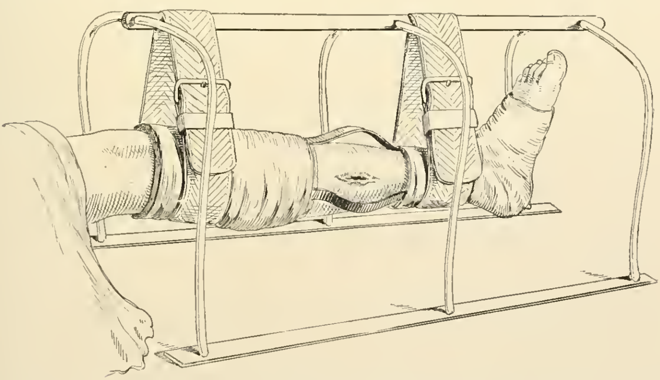


Fig. 100.—Interrupted Plaster-of-Paris Splint. (From Cheyne and Burghard.) A form of splint adapted to compound fractures. The illustration shows how the iron bars, incorporated with the plaster bandage, are bent to allow free access to the wound. The limb is slung from a cradle; as a rule, the plaster bandage would be carried above the knee.

After thorough disinfection of the wound and limb and proper fixation of the bones, the limb must be placed in a suitable splint in order to secure immobilization and prevent displacement of the fragments, even when attempts at direct fixation

have been made. Tenotomy is often necessary to proper reduction and frequently aids in the after-treatment of the more serious cases.

The swelling following a compound fracture is usually far more extensive than after simple fractures; hence it is frequently a matter of great importance to adjust

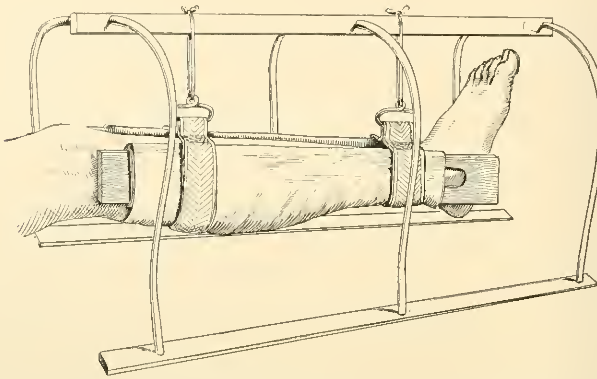


FIG. 101.—"Fracture Box" or "Box Splint" for Fractures of the Leg. (From Cheyne and Burghard.) The two lateral splints are rolled up in a folded sheet, fastened to the limb by straps and buckles, and the whole apparatus slung to the cradle. A bandage is usually also put on over all.

a splint or external fixation dressing that will make allowance for subsequent swelling, and that need not be removed or disturbed in order to inspect or redress the wound. In fractures of the leg the author still employs the 'fracture box of our fathers' as being the safest and most comfortable temporary splint that can be used.

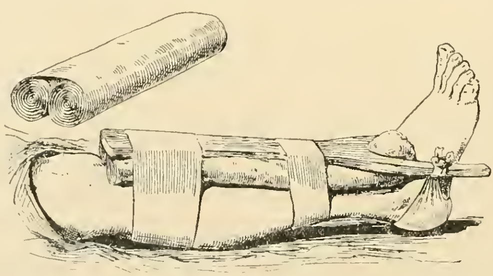


FIG. 102.—Syme's Horse-shoe Splint. (From Cheyne and Burghard.) The sling embracing the heel may be made of elastic webbing. The smaller figure, at the left, shows the method of rolling up lint to make the padding. The splint is very commonly supplied with two holes bored in its upper end. It is then secured to the upper part of the leg by one or two turns of a bandage.

For compound fractures of the thigh Buck's extension apparatus, with modified details, answers every purpose, and later, when all acute symptoms have subsided, a fenestrated plaster-of-Paris splint (von Esmarch) may be safely applied.

The patient must be placed in a narrow bed with a firm hard mattress. Later, there is frequently a tendency to eversion of the foot. This may be corrected by pinning a strip of Canton flannel along the inner side of the leg bandage, passing it under the leg and over the side splint, where it is secured by several tacks. This suspends the leg, taking pressure from the heel, and causes the required inversion. (Dr. Nathan Clarke Morse, of Iowa, on Postoperative Treatment.)

In the opinion of some surgeons *ambulatory dressings*, as they are called, have their place in the treatment of many cases of fracture of the lower extremity. They are made in a great variety of forms. For example, some are made of plaster of Paris, while others consist of some special kind of hip-and-leg splint (Fig. 103), after the order of orthopedic appliances; some are hinged at the knee, while others are not; some take the support of the body by means

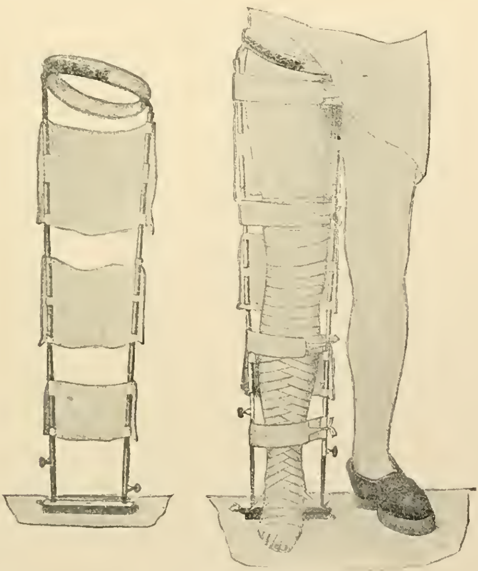


FIG. 103.—von Bruns' Ambulant Splint. (Hoffa.)

of strips of adhesive plaster, or by a padded extremity that presses upon the perineum, etc., while others have the dressing so arranged as to grasp the prominences about the knee and the conical surfaces of the thigh. The object of all these contrivances is to transmit the weight of the body to the ground direct from the upper attachment, without use of the foot, thus preventing transmission through the fractured portion of the leg or thigh. It is claimed, in behalf of this method of ambulatory treatment, that it prevents to some extent shrink-

age of the muscles, retains their contractile powers, entails less anæmia and debility than if the patient is confined to the bed, and favors, in many instances, a more rapid and satisfactory union of the broken ends of the bone. The main point is to see that the reduction is perfect and the immobilization complete. Special care is to be taken to keep the foot in its proper axis and in normal relation to the limb, and to prevent pressure from being made on bony prominences or upon the integument at any point, for fear of causing excoriation and sloughing.

Although this ambulatory treatment is almost necessarily limited to simple fractures or to slight compound injuries that are early converted into simple ones by appropriate treatment, yet such measures undoubtedly have a legitimate place in the treatment of fractures of the leg, and should receive due consideration.

Fractures of the Bones of the Foot.

Fractures of the bones of the foot comprise about one and a half or two per cent of all fractures. The os calcis is most frequently broken, and the astragalus comes next in order. Direct force, in the shape of a blow or a fall upon the foot, often produces compound fractures. In the case of fractures of the os calcis and the astragalus, however, the causative agent is, as a rule, an indirect force. The scaphoid, cuboid, and cuneiform bones are broken with about equal frequency by a direct or an indirect force. Fractures of the metatarsals and phalanges are almost invariably produced by direct force, and are frequently compound.

Fractures of the Os Calcis.

Fractures of the os calcis are often caused by falling and striking directly on the feet. (Fig. 103.) They should be recognized early, and proper treatment instituted, for failure to diagnose the fracture and properly immobilize the foot often results in necrosis. Fractures of the tuberosity are usually produced by violent contraction of the muscles of the calf, which displace the detached fragment upward. The contraction of the tendo Achillis is offset by the plantar fascia and muscles arising from this part of the calcaneum. The symptoms are usually clear, viz., inability to stand or walk, displacement of the tuberosity (heel), and crepitus elicited by drawing down the fragment. Loss or impairment of the power of extending the foot, and lowering of the plantar arch, may also be observed in these cases. If the fragment cannot be replaced and held there, it should be exposed and fixed by an ivory or bone peg or by suturing. Fractures involving the sustentaculum tali are rare and are usually associated with other injury to the calcaneus. Sometimes the fracture produces a pes valgus. Comminuted fractures are produced by compression, the violence being applied directly to the heel. The severity of the fracture

depends upon the amount of the weight and force. Fissures without displacement cannot very well be detected in this fracture, yet persistent pain and loss of function, with effusion, should be sufficient evidence to warrant the placing of the foot in some kind of immobilizing apparatus. Unusual pain should always demand a careful investigation, and, if there be any doubt with reference to the nature of the injury, the foot should be treated as if a fracture did exist. There is in some cases a broadening of the heel with discoloration, and the grooves on either side of the tendo Achillis are often obliterated.

Fractures of the Astragalus.

Fractures of the astragalus are commonly the outcome of falls from a height and striking squarely on the feet. Under these conditions the body of the bone is broken between the tibia and the os calcis. Fracture of one or more of the immediately contiguous bones not unfrequently happens at the same time. There is no established line of fracture and the fragments vary in number and in their relations with each other. Fracture is frequently produced by a violent flexion of the foot. A fracture of the neck of the bone is often attended with a slight fracture of the internal malleolus. There may be little or

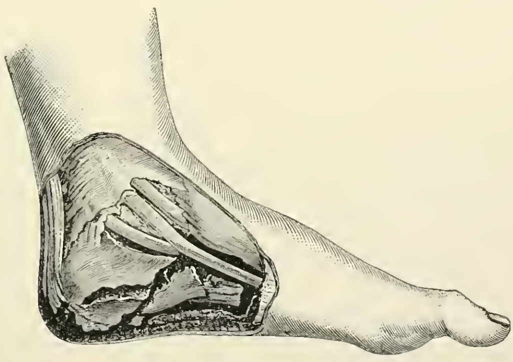


FIG. 104.—Fracture of the Calcaneus by Crushing. (Anger.)

no displacement, and in some cases there is a backward displacement, the fragment sometimes appearing posteriorly between the bones of the leg and the tendo Achillis.

The diagnosis of fracture of the astragalus may be determined by the following symptoms: A limitation of motion, tenderness on pressure, and inability to stand or walk upon the foot. There is little or no displacement, and the condition is oftentimes mistaken for a severe sprain. Persistent swelling with marked tenderness and some extravasation of blood, and crepitus, should

be regarded as sufficient evidence of a fracture. In fracture of the neck of the bone, the head, when displaced, may be noted. In all doubtful cases, however, it is well to anæsthetize the patient and thus determine the presence of a false point of motion and perhaps crepitus. It is wiser, when possible, to forestall anæsthesia and manipulation in diagnostic effort by the utilization of x-rays, preferably in both feet, for purposes of comparison.

Fractures of the Other Tarsal Bones.

In fractures of any other of the tarsal bones, the following symptoms are usually present: Pain, swelling, mobility, crepitus, widening of the foot at the point of fracture, and, as Pick has pointed out, a loss of the arch of the foot. Crepitus may not be detected at first, on account of the natural wedged condition of these bones, and later, even after swelling has subsided, it may not be possible, without the employment of a general anæsthetic, to elicit this symptom—a procedure which is rarely advisable. As a rule, it can be elicited only by rotating the foot while the heel is firmly held. The pain usually becomes more intense when the foot is flexed. If displacement exists, the diagnosis is clear. There is always loss of function, particularly to be noticed in an attempt to walk. The real condition can be ascertained only after the swelling has subsided. Fragments can occasionally be felt just beneath the skin, and their presence usually occasions some deformity.

The course of these fractures of the foot is usually characterized by a long period of recovery; and, even after recovery has taken place, there remains, for several months or even for years, a more or less persistent pain in the sole of the foot. In exceptional cases a flat foot develops, and with this condition is associated some eversion of the foot. Motion may be free in the ankle joint, but impaired in the calcaneo-astragaloid and medio-tarsal joints.

In the treatment of fracture of a bone of the tarsus the first step required is to reduce the deformity; and, in order to reduce it properly, it will often be necessary to employ a general anæsthetic. The reduction is effected by means of extension and counter-extension and direct pressure on the displaced fragments. The maintaining of the fragments in position is not always easy, it being often necessary for this purpose to continue the forces that restored them to place. Local pressure made by means of a tourniquet and pad, or established in some other way, may be utilized, preferably the former, since continuous and well-regulated pressure can thus be best secured. If, however, the os calcis (the heel) be fractured as above described, the foot should be extended as far as is consistent with comfort, the fragment pushed down into place, and the foot and fragment thus confined by means of a plaster-of-Paris dressing encasing the foot and the leg quite up to the knee. The application of the plaster bandages in a figure-of-8 form around the heel, thence under the sole and over the dorsum of the foot, will aid the retaining power. A lighter

splint applied at the front of the foot and leg, and meeting the same indications with the aid of adhesive plaster and bandages, may be used.

If no deformity exists in fracture of the tarsus, a temporary dressing should be applied and the swelling reduced by the application, for several days if necessary, of an ice bag or perhaps of an evaporating lotion. After the swelling has subsided, the foot should be maintained in a position at a right angle with the leg and a permanent immovable dressing applied. The fracture box is recommended by many, but plaster of Paris, I believe, makes a much better and more comfortable dressing and should be worn for six weeks. Should the dressing become loose, it should be removed and a new one applied in its place. In case a projecting fragment cannot be forced into place, it should be excised, for, if it be left, it will be likely to cause ulceration or sloughing of the tense soft parts over it, as well as to prove a source of irritation thereafter from pressure of boot or shoe. In compound fractures, drainage is necessary, and provision must be made for it by cutting out, in the immovable dressing, a door or fenestra over the wound.

The foot should be kept elevated for a time. While it is not always necessary to keep the patient quiet longer than the first ten days or two weeks, yet, if he be allowed to sit up, the foot should not rest on the floor. The allowing of patients to walk on crutches should be at first practised with discretion, as the determination of blood to the foot, in the upright position, may keep up the swelling and possibly cause embarrassments requiring operative relief.

The bearing of the weight of the body on the injured foot should be deferred for five or six weeks, and possibly longer, depending on the degree of infliction caused by the act. The lowering of the main arch of the foot, because of the impairment of the posterior pillar (the os calcis) is not unusual in fracture of that bone. Also this deformity may follow fracture of the astragalus. Fracture of the sustentaculum tali may cause inversion of the foot. It may be necessary for the patient to undergo a long course of hot-water baths, massage, and passive motion before a serviceable limb is assured.

Fractures of the Metatarsal Bones and the Phalanges.

Fractures of the metatarsal bones and the phalanges are readily detected, but not so easily as are those of the hand. They are treated on the same plans as those recommended for fracture of the corresponding bones of the upper extremity. Rest of the injured foot is of importance for apparent reasons. The foot should be kept quiet for four or five weeks. Union usually results without any functional impairment. Fractures of the toes, however, owing to their comparatively small size, are best treated—except in the case of the great toe—by separating with pads and binding together. A splint moulded to the great toe and to the outer and inner metatarsal bones, will, when bandaged in place, meet the indications.

PSEUDARTHROSIS.

By T. TURNER THOMAS, M.D., Philadelphia, Pa.

General Remarks.

The term "pseudarthrosis" signifies an abnormal point of motion in a bone, the result of a fracture which has failed to unite after nature's efforts at repair have been exhausted. Delayed union or temporary failure is present when union is delayed beyond the time ordinarily required for consolidation.

The difference between delayed union and pseudarthrosis or ununited fracture, while distinct, is more or less an arbitrary one. It is distinct in the sense that the term "delayed union" is applied to those cases in which there is more than a fair probability that the process of repair is still in progress and that union will later result from simple methods of treatment; while "ununited fracture" is applied to those in which all efforts at repair on the part of nature have ceased, and in which only vigorous efforts on the part of the surgeon will renew them. Unfortunately, we cannot decide in the early stages which cases will finally unite and which fail. We are, therefore, compelled to adopt a more or less arbitrary rule in distinguishing between the two conditions. When the fracture fails to unite in the time usually sufficient in the particular bone involved, we call it delayed union. The term ununited fracture or non-union is not employed until after three or four months have elapsed, when it is believed that, in most cases, nature's efforts have been exhausted. A still more arbitrary rule is adopted by some surgeons, who assert that if at the end of six weeks consolidation has not occurred the condition is one of delayed union; and if, at the end of three months, union has still failed, ununited fracture is present. While this will serve as a good working rule, it should be borne in mind that some bones, as the clavicle, usually unite in three or four weeks; while others, as the femur, require from six to eight weeks for union. On the other hand, cases have been reported in which union had been delayed considerably longer than three or four months, and in which the unaided efforts of nature, except for the correction of errors in the treatment, were sufficient to produce consolidation. Senn reports a case of fracture of the femur which united after immobilization and extension in two months, in which union had been delayed a year and a half after the accident. Delayed union may also be defined as the earliest manifestation of pseudarthrosis, and its most important characteristic is that in the great majority of instances union later develops.

VARIETIES OF NON-UNION.

Ununited fracture indicates a failure of ossification of the newly formed reparative material at the seat of fracture. This may result in one of several degrees of insufficiency of union. There may be an entire absence of any

a *b*

FIG. 105.—Corson's Case of Excessive Bone Atrophy Following Fracture. (*Annals of Surgery*, Oct., 1898.) *a*, Right forearm; *b*, left forearm.

connecting bond between the two fragments, which then become more or less rounded and atrophied, resulting in a freedom of motion of the fragments on each other and usually a shrunken flail-like character of the limb.

Much more frequently there is a fibrous connection between the fragments, the uniting fibro-ligamentous bands varying in length and strength according to the distance between the ends of the bone. The medullary cavity may be closed at the ends, which are more or less rounded and covered by a fibrous tissue like the periosteum. The atrophy and rounding of the fragments are due to a rarefying osteitis, which, in some cases, may continue until the greater part of the bone has been absorbed.* Corson reported an interesting case of this kind (see Fig. 105). The right ulna probably had been fractured in a fall ten years before, the injury being treated simply with a lotion; and, five years before, both bones of the left forearm had positively been fractured and properly treated. Except for paralysis agitans of the left side of six months' duration and a slight senile bronchitis when Corson saw her, the patient was healthy and vigorous for her age. A remarkable instance is that recorded in the Boston *Medical and Surgical Journal*, 1838. Good union had already begun in a fracture of the humerus, when a refracture occurred and was followed by a rapid absorption of the whole bone from the axilla to the elbow. Gross refers to a similar case in which the whole humerus, except the condyles and a little of the head, was absorbed in six years following the fracture. This fracture had been preceded by another an inch and a half above, three months before, which united in the usual time. The general health remained unimpaired, and the muscles of the arm well developed.

Finally, and in rare cases, a true joint may be formed at the seat of fracture. The ends of the bone when in contact may become covered with a layer of cartilage, and this with a form of synovial membrane, smooth and polished, the fibrous uniting structure forming a capsule containing a lubricating fluid, synovial in character. Of seven such cases collected by von Bruns, four involved the humerus, two the forearm, and one the leg. Diseases characteristic of joints, such as arthritis deformans, and foreign bodies have been known to affect these false joints.

At times the union may be partly fibrous and partly bony. This was demonstrated in a fracture of the fibula operated on by Gould. The patient complained of extreme pain on special movements of the foot. At operation it was established that the line of fracture had united at both ends by bone and in the centre by fibrous tissue. This fibrous tissue was adherent to the sheaths of the surrounding muscles, so that on movement of these muscles pain was produced by dragging on the adhesions.

Frequency.

While delayed union is relatively common, ununited fracture is generally conceded to be rare. Mr. Walker, of Oxford, met with only 6 or 8 cases in more

*Annals of Surgery, Oct., 1898.

than 1,000 fractures which he had treated. In nearly 4,000 fractures treated at the Middlesex Hospital, Lonsdale found only 5 or 6 ununited, excluding those occurring within a capsule. Pierson collected 367 fractures, only 1 of which was ununited. Karmilow places the frequency at 1 in 300 or 400, Hamilton at 1 in 500. Of 489 fractures at the Zurich Clinic, 6 were ununited and in 16 delayed union was present, which would seem to be a high percentage of failure of union. On the other hand, Norris found that of 946 recent fractures received at the Pennsylvania Hospital not one resulted in non-union.

Etiology.

The exact etiology in most cases is difficult to establish, and this is probably responsible for the large variety of conditions assigned as causes. These are generally divided into the constitutional and local. Although the failure of union has been attributed to numerous constitutional disturbances, it is very probable that in most cases some local factor is at fault. The proper appreciation of this fact is important. To assume that a suspected or recognized dyscrasia or a constitutional condition is responsible for the delayed union, and to act on that assumption to the extent of directing one's efforts to constitutional treatment only, and neglecting to seek and correct local disturbances, would in most cases lead to the loss of very valuable time. In the absence of any positive evidence, it would be much safer to assume that the cause is local, and to direct one's attention to the dressings, which may be faulty or may have been disturbed by a rebellious patient. It is not intended here to imply that the constitutional treatment is to be neglected, but that it should be of secondary importance to the local. On the other hand, some surgeons attach much more importance to constitutional causes than do others. Pilcher maintains that they indisputably determine non-union in many cases, and points to the fact that in many instances defective immobilization fails to prevent union. He refers to two patients, in both of whom, at two different periods, fractures occurred, union being delayed in each fracture, showing that a constitutional predisposition probably existed. Most surgeons, however, are of the opinion that the local are by far the more important causal factors. Agnew, in discussing local causes, says that in most instances of delayed union, and especially in those of non-union, which came under his care, the cause could be traced to certain influences, among which may be mentioned the presence of a foreign body, as a fragment of necrosed bone or a ball. He also adds that not unfrequently the failure is due to a defective dressing or a refractory patient.

Constitutional causes are of importance, probably through their influence in depressing cellular activity in general, as from anæmia following serious hemorrhage, or from exhausting conditions. Agnew says that he has found

shock in a number of instances to have retarded consolidation. Only those constitutional causes commonly alluded to in connection with pseudarthrosis will be referred to here.

Pregnancy and *lactation* may have some influence in delaying consolidation. It is likely, however, that the blood required by the uterus, and its consequent deficiency elsewhere, will account for any influence it may have in retarding ossification. It has been suggested that the disturbance in repair is due to the abstraction, from the mother, of the calcium salts necessary for the development of the fœtal skeleton. Packard says that against the cases adduced in proof of this cause must be set a great many in which the cure has been rapid, and he refers to such a case which came under his care at the Episcopal Hospital.

Many cases of delayed union have been ascribed to *syphilis*, yet it is more than likely that this disease has little or no influence on the process of bone repair, beyond its effect in lowering general vitality. The coexistence of syphilis and slow union has been reported many times, but the evidence of a causal relation is not convincing, and the weight of authority is against it.

Cancer, aside from localized deposits in a bone, will not interfere with union. Brodie and Liston reported cases of cancer in which fractures occurring from slight violence united as if they had been in healthy bones. Fractures occurring at the seat of cancerous deposits, leading to absorption of bone tissue, will probably not unite.

Scurvy, and *fevers* of a depressing nature, by inducing great debility in the vital powers, may interfere with the reparative process. Improper abstinence from food as in the treatment of obesity, and the removal of an habitual stimulant, have been said to act in a similar manner.

Disturbance of the nervous system may also have some influence in delaying the healing of fractures.* Girdner says that patients suffering from general paresis of the insane show a greater frangibility of the bones and a greater liability to delayed union, soft fibrous union, and complete non-union, than do those who suffer from some other form of insanity. That the interference with union was not due to lack of co-operation on the part of the patient was shown in the first place by the fact that these patients were generally more manageable than those with most other forms of insanity, and in the second place by the fact that Girdner was always able to obtain union and useful limbs when the patients suffered from any other form of insanity, as acute or chronic mania. In nearly all of these it was more difficult to adjust and immobilize the fragments, owing to the restlessness present, than in cases of general paresis. Dennis refers to a case in which there occurred a spinal injury with fracture of the humerus and leg of the same side. The humerus united, but the leg failed. Other cases, however, are reported in which under similar circumstances union of a fracture below the seat of injury in the cord has resulted without delay.

*Annals of Surgery, 1897, i.

The *cutting off of the main blood supply* of a limb must have some disturbing influence on the reparative process in bone, as it does in that of the soft tissues, but with the return of a good blood supply from the collateral circulation union will probably proceed as in the normal limb. Brodie showed, from experiments on lower animals, that, in the first week after ligature of the main artery, union is delayed for about a week, but at the end of that time it goes on as though no such operation had been done. The following case, which the writer had under his care at the University Hospital, illustrates the possibilities of a similar condition. As the result of a crushing accident there was a comminuted fracture of both bones of the leg, and the circulation below was so compromised that no pulsation could be felt at the ankle in either of the tibial arteries. The greater part of the leg soon became threateningly pale, cold, and œdematous, and later gangrenous areas appeared. These proved to involve only the superficial tissues, and to be localized to small portions of the surface. For the first week the question of amputation was held in abeyance, and was at the end of that time considered unnecessary. Union was delayed until the thirteenth week, when the patient was able to support the weight of the body and to walk without discomfort at the seat of fracture. The comminution of the bones, the degree of elevation employed, and the difficulty in providing immobilization could in themselves account for the delay in union. Other causes giving rise to similar disturbance of the blood supply are: too tight bandaging, injury of the veins, and thrombosis. Berard called attention to the fact that the union of the various epiphyses in the long bones of the extremities with their shafts is related to the direction of the nutrient arteries; and Gueretin's statistics seemed to show that non-union was more common at those ends of the long bones away from which the nutrient arteries were directed. On the other hand, Norris, after an analysis of forty-one cases, failed to confirm this view.

Advanced age can scarcely be considered as a predisposing cause of imperfect union in fractures. Horner reported a fracture of the humerus in a woman ninety years, Agnew a fracture of the thigh in a woman ninety-five years, and Gross one of the humerus in a woman one hundred years of age, in all of which cases consolidation occurred in the normal period. Amesbury, who saw about ninety cases of ununited fracture, and von Bruns, who collected statistics bearing on this point, concluded that pseudarthrosis is more rare in childhood and old age than in the intervening period of life.

Fragilitas ossium, a condition in which fractures occur from slight causes, and in which one would naturally expect union to be slow, does not interfere with the process of union, as is shown by the reported cases. The writer saw at the Philadelphia Hospital a case of this kind in which at different times twenty-four fractures had occurred, every one uniting with the usual rapidity.

While the *local causes* are more frequently apparent than the constitutional

and can in some cases be positively demonstrated, there is considerable difference of opinion as to their individual importance. That which will demand the greatest attention from the physician is the lack of sufficient immobilization of the fracture. It is probably the most frequent cause of pseudarthrosis and may be the result of a faulty dressing, too frequent examination by the physician, or of interference on the part of the patient, who, in seeking relief from pain or fatigue, loosens the bandages or relaxes the extension.

Fig. 106.—Ununited Fracture of Both Bones of the Leg, with Overlapping. (Skiagraphed by Dr. H. K. Pancoast.)

Too wide an interval between the fragments, as from necrosis in a compound fracture or the removal of detached fragments in a compound comminuted fracture, may result in an insufficient deposit of callus to bridge the gap. On the other hand, cases have been reported in which a separation of the fragments of from two to six inches has been overcome and the bone reunited with little or no shortening in the affected limb. The time required for union in these

cases is, of course, prolonged and the liability to failure is increased. Too great overlapping may also interfere with union by removing the fractured surfaces from each other by too wide an interval (see Fig. 106).

The *interposition of foreign tissues*, such as tendon, muscle, bullets, or necrosed bone, sometimes seems to offer an insuperable barrier to consolidation (see Fig. 107). Interposition of fibrous tissue occurs in almost every fractured patella, either from the offending instrument in fractures by direct violence, or from atmospheric pressure in fractures by indirect violence. Muscle tissue frequently intervenes in fractures of the humerus and femur, where the surrounding muscles are closely adherent to the bone. Roberts reported a case of ununited fracture of the humerus in which, after the bone had been exposed by incision, it was impossible to reduce the fragments. The stripped-up periosteum and muscles held such relation to the fragments that resection of the ends of the bone was necessary before its continuity could be restored. In a case of Morton's involving the same bone, extreme pain, spasm, and finally non-union resulted from interposition between the ends of the bone of a small fragment, which lay across. A portion of the muscle and the musculo-spiral nerve were also implicated. Whenever possible the intervening substance should be disengaged by extension and manipulation; and in these cases, as well as in those in which overlapping or separation of the fragments exists, grating of the fractured surfaces should be obtained to determine that the fragments are in proper position.

Fig. 107.—A Longitudinal Section of an Oblique Supracondyloid Fracture of the Femur. No union has occurred, the upper fragment having pierced the quadriceps tendon, which is seen between the two fragments above the patella. (Specimen in St. Bartholomew's Hospital Museum.) (Treves.)

Compound fractures which become infected may result in delayed or non-union, although this is far from being the rule, especially since the introduction of antiseptic methods of treatment. Pilcher calls attention to the fact that of 2,900 gunshot fractures of the humerus, in the Civil War, only 6 resulted in non-union. The depressed constitutional condition in these compound fractures probably has little to do with the failures in union that do occur. The local effects, such as the loss of bone substance, persistent suppuration, and the intervention of a necrosed fragment of bone, sufficiently explain the interference with the process of consolidation. Sometimes the callus which develops about a loosened fragment is in turn more or less destroyed by it and the union delayed or prevented.

It is generally conceded that in some cases, in which the treatment has been carefully carried out and no local or constitutional cause can be determined, non-union will result. In view, therefore, of this fact, and the wide variety of causes assigned to this condition, it becomes necessary to speak with caution, in the presence of the patient or his friends, lest the physician be unnecessarily accused of carelessness and the result be attributed to his treatment. On the other hand, it is a well-known fact that fractures frequently unite in the presence of very careless treatment, and even where no treatment at all has been applied. Where two bones have been broken in the same patient, either in the same or in different portions of the body, and where the treatment for both is equally skilful, one may unite and the other fail. The only case of delayed union in fracture of the clavicle seen by Pilcher occurred in an apparently robust young man, in whom unusual care to immobilize was taken by the surgeon. At the end of four weeks, when Pilcher first saw him, no callus had formed and the fragments were as movable as if the fracture had just been sustained. Two weeks after discarding the dressings and going to work, he returned with an abundant ossifying callus uniting the fragments.

Diagnosis and Prognosis.

The diagnosis of delayed union depends chiefly upon the detection of a false point of motion at the seat of fracture. There will usually be considerable tenderness upon pressure; and upon an attempt to use the limb, pain, swelling, and œdema develop.

The prognosis will vary with the part of the body and the particular bone or bones involved, the degree of mobility at the seat of fracture, the condition of the ends of the bone, the age and general health of the patient, and the treatment employed. In non-union of the bones of the upper extremity, the degree of disability will, generally, be less than if the lower extremity be affected. Instances of ununited fracture have been reported in which the motion at the seat of fracture and the disturbance of function have been so slight that it would probably be advisable to avoid all treatment, especially in old people. Peters refers to a case of Sir W. Fergusson, in which the man had such a useful arm, though it was the seat of pseudarthrosis, that he passed a searching examination as a recruit and was accepted for the army. A similar case involving the forearm was seen by Peters, in which there was such slight impairment of function that the man was able to earn his living as one of the crew of a steam thresher. Before the introduction of antisepsis, a great variety of supporting braces for pseudarthrosis of the upper extremity had been employed. They were generally modified or adapted to the needs of the particular case. J. Hutchinson was very partial to their use, and reported one case in which a sportsman by means of such a support was able to manage

his gun very fairly in the field. Even in the lower extremity they have been used to great advantage. Where operation is inadvisable for any good reason, the prognosis for a fairly useful limb may still be good with the aid of a suitable apparatus such as that devised by H. H. Smith (see Figs. 108 and 109), which has the still further advantage of stimulating callus formation and possibly of bringing about consolidation. In most cases, however, particularly in the lower extremity, when pseudarthrosis is well established, the prognosis is best promoted by the performance of an operation, and, in the light of our present knowledge of antiseptic technique and methods of fixation, the open operation, with fitting together of the freshened ends of the bone and mechanical fixation, will be the treatment of choice.

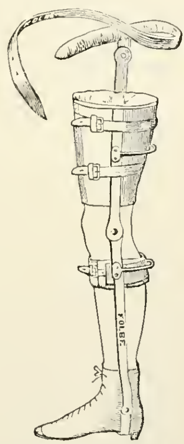


Fig. 108.—Smith's Apparatus for Ununited Fracture of the Thigh. (Agnew.)

Treatment.

History.—Although our knowledge of the process of bone repair has made little progress in the past century, and although since the appearance of Norris' most excellent paper in 1842 practically nothing of value has been added to the literature of the subject, the improvement in the results of treatment has been very encouraging. Few surgical conditions have been the object of so many modes of treatment as the failure of bony union after fracture, and, although the majority have become obsolete, there still remains, in the opinion of different surgeons and in different countries, a considerable divergence of views. Among those methods which have been vaunted in their day, but which have passed out of use, may be mentioned the local application of blisters or counter-irritants like iodine, compression, salivation, and the seton. Acupuncture and electropuncture to the seat of fracture have still a few adherents, but they probably have very little value. The seton is of some interest in this country, as a product of early American surgery. It was first demonstrated and introduced into general use by Physick, of Philadelphia, and although strongly opposed from the beginning, particularly by English and French surgeons, such as Brodie, Syme, Larrey, and Velpeau, it had many strong supporters, especially in America. Norris said that the results in America had proved it to be one of the safest, least painful, and most effectual of the operations for this condition.

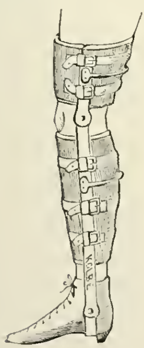


Fig. 109.—Smith's Apparatus for Ununited Fracture Below the Knee. (Agnew.)

To the credit of the older writers, however, it must be admitted that the

methods of treatment in vogue to-day are merely modifications of those adopted in the earliest times. Friction, produced by rubbing the ends of the fractured bone together, which is almost universally recommended at the present time as an early measure, is probably the oldest method of treatment for this condition, and was spoken of by Celsus. Avicenna had done the open operation to freshen the fractured surfaces, although he considered it a dangerous and frequently fatal operation. Wiring the teeth for persistent deformity in fractures of the jaw was done in the time of Hippocrates. The chief objects of treatment to-day, which are to remove local disturbances, to provide fixation of the fragments, and to stimulate bone growth, were evidently recognized in those times.

Non-operative Methods and Subcutaneous Operations.—The most important factors influencing the kind of treatment to be adopted are: the period elapsing since the occurrence of the fracture, the degree of separation of the fragments, and the condition of the ends of the bone. If, in the ordinary fracture, at the end of the time usually required for repair in the particular bone fractured, union has not taken place and is therefore simply delayed, it will be well to assume, if no other cause is apparent, that the treatment has been at fault, and to keep in mind the fact that the disturbance is most frequently due to imperfect apposition of the fragments and a lack of sufficient immobilization. Any possible correction of displacement should, therefore, be made at once, and as perfect fixation of the fragments by dressings be provided, before proceeding to more vigorous methods of treatment. If the fracture has involved the lower extremity, and the patient has been continuously in the recumbent position, there will probably be little or no swelling present at this period, when the best dressing will be an immovable one, as the plaster-of-Paris cast. This should be applied carefully and evenly, with the fractured ends in as good position as possible. Once applied it should not be removed until full opportunity for consolidation has been provided. This will vary from six to ten weeks according to the bone involved. In most cases at the end of this period consolidation will have been effected.

Should union still be absent, more vigorous methods must be employed to excite callus formation and to obtain more accurate apposition of the fragments. This can best be accomplished at this stage by direct irritation at the seat of fracture, and the application, wherever possible, of an immovable dressing.

Of the many methods that have been practised to stimulate the reparative process, *friction* by vigorous rubbing of the ends of the bone against each other is one of the most valuable. It is at the same time the least dangerous and the most effectual of the simpler methods. But, in order to obtain the greatest good, it must be thorough, and should not be employed in old cases with fragments having rounded, atrophied, and smooth surfaces, and probably

firm fibro-ligamentous bands between them. In the progressive treatment of a stubborn case, its place is early, that is, in the stage of delayed union; and, as in all methods of forcing nature's efforts, it should be associated with careful constitutional treatment and the best possible hygienic conditions. To obtain the full benefit from friction, an anæsthetic is necessary, which should be administered to the state of complete relaxation, in order to overcome muscular spasm, to avoid pain, and to permit, therefore, vigorous handling of the parts. It should aim, not only at stimulating callus formation and accurate replacement of the fragments, but also at removing as far as possible all fibrous and other tissues from between the ends of the broken bone. After complete relaxation from the anæsthetic, the first efforts should be directed toward providing free motion at the seat of fracture, to such a degree that, when overlapping exists, the fractured ends, if possible, may be apposed to each other and freely rubbed together. To do this, great force will usually be necessary, the bending being carried in all directions to nearly a right angle, and the fragments freely rotated on each other. The bone is then seized on each side of the fracture, and vigorous efforts are made to grind away all intervening tissues until crepitus is well established. The fragments are then properly adjusted and immobilization provided for from six to ten weeks according to the bone involved. It may, however, be necessary to repeat this procedure before sufficient reaction has been established or union obtained. A plaster cast should, therefore, not be applied until an opportunity has been afforded to observe the local effect of the manipulation and to permit the acute swelling to subside.

In some cases the fragments will still fail to grate upon each other, probably from the altered condition of the ends of the bone, too wide separation or too great overlapping, or the intervention of firm fibrous bands between them; but, if the cases are judiciously selected, this can usually be avoided. Karmilow states that the method was successful only forty times in four hundred cases in which it was employed. This was probably due to an improper selection of cases or a lack of vigor in the application of the method. It should be borne in mind that there is sometimes danger of seriously injuring adjacent important structures, as the musculo-spiral nerve in pseudarthrosis of the middle third of the shaft of the humerus. The nerve is so closely bound to the bone in its groove in this region, that it is frequently injured at the time of the occurrence of the fracture, or later is enveloped in the callus. Vigorous manipulations in the friction treatment for non-union may, therefore, partially or completely rupture and paralyze the nerve. In this region other methods should be adopted, and in most instances it will be best to proceed at once to an open operation.

In pseudarthrosis of the lower extremity, particularly of the leg, *continuous friction* at the seat of fracture may be applied, by the use of an appara-

tus which will immobilize the fragments and take the weight above at the bony prominences about the knee or at the hip, thus permitting the patient to walk about. Irritation will be excited by the unavoidable slight weight and movement transmitted to the seat of fracture, and thus increased bone growth favored. As stated, in referring to the prognosis of pseudarthrosis, the best apparatus, generally, is that devised by Smith (see Figs. 108 and 109), which can be adapted for a fracture of the leg or thigh.

The so-called "*percussion method*" has had many supporters, but is little used at the present time. It was introduced by H. O. Thomas, of Liverpool, and consists in exciting about the fracture a hyperæmia and exudation, by light hammering with a small rubber-covered copper mallet. The parts about the fracture should be percussed for five or ten minutes every 48 or 72 hours, with the mallet, until the desired degree of reaction has been created. This will be shown by the appearance of redness, heat, pain, and moderate swelling, when the fragments are to be immobilized for five or six weeks.

While the *injection of irritating substances* in and about the line of fracture had its greatest vogue in the days when open operation was a very dangerous proceeding, it has some supporters at the present time. von Bergmann advises it as one of the milder measures, and recommends the use of tincture of iodine, five-per-cent carbolic-acid solution, four- to ten-per-cent chloride-of-zinc solution; he says, further, that the surgeon may consider subcutaneous tearing of the intersubstance, electropuncture, or thermopuncture. Moore states that the injection of glacial acetic acid has been employed at the Melbourne Hospital for many years. The injection of a few drops is sufficient to effect a cure, and this has been accomplished in some cases where wiring of the fragments has failed.

Bier's method of inducing venous congestion has been employed to increase bone growth in delayed union (Dumreicher, Helferich). The hyperæmia may be localized to the region of fracture by placing the constricting bandage above, or above and below the line of fracture, but not over it. Nicoladini recommended an interrupted use of the method at intervals of from two to six days. Wiener states that the venous hyperæmia, like that which accompanies inflammation, tends to remove detrimental substances and to form new tissue. Care should be observed in applying the constriction, which should aim to obstruct only the superficial veins and not the deeper vessels. Coolness of the parts below is a sign of too severe constriction. When the necessary reaction has been produced, the limb may be immobilized by plaster-of-Paris or other efficient splints. In the lower extremity, especially in ununited fracture of the bones of the leg, this method may be combined with the continuous irritation provided by the ambulatory apparatus of Smith.

Subcutaneous perforation of the fragments, by means of specially devised drills, was first used by Dieffenbach, but was brought into prominence by

Brainard, of Chicago. Until recent years it was very much practised, but with the development of modern antiseptic technique it has largely passed out of use. It has the advantage of avoiding a cutting operation, and in rare cases may be serviceable at the present time. The method of procedure is as follows: the skin is perforated with the instrument or a narrow-bladed bistoury, and an opening made to the seat of fracture. A special perforator is then introduced along the track of this opening, and is made to pass through both fragments and the line of fracture at several points, without removing the drill from the wound in the soft tissues. The number of bone perforations will depend on the size of the bone fractured. A drill with a triangular point is considered preferable to one with a flat point, as it is less liable to break or to split the bone. This accident occurred in a case reported by Weir, in consequence of which severe infection followed and the patient died. Brainard,

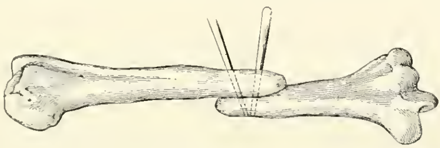


FIG. 110.—Fixation of the Overriding Fragments by Two Ivory Pegs. (Von Bruns.)

from his experience, considered that, generally, two or three bone perforations were sufficient for the first attempt. Where no foreign body intervened and the fragments were closely apposed, the method was said to be usually successful, although a repetition was often demanded. Dieffenbach became dissatisfied with this method and added the introduction of *ivory pegs* through the bone perforations (see Fig. 110). As ordinarily performed this operation will not provide for the removal of intervening foreign tissues nor for freshening the ends of the fragments. The wound that is necessary is quite or almost as dangerous, with careful antisepsis, as one large enough to expose the fragments freely, so that there is little reason for preferring it to the modern operation of resection. White says that these methods of drilling and pinning with ivory or iron pegs were far more frequently followed by failure than by success.

Open Operation.—The most practical and effectual treatment for well-developed pseudarthrosis is free incision, resection or freshening of the ends of the bone, and direct fixation of the fragments by one of the mechanical devices employed at the present time. It permits the thorough removal of intervening fibrous or other foreign tissues, and converts the conditions into those of a recent compound fracture, under favorable circumstances. Resection was introduced into general use by White, of Manchester, in 1760, who removed the ends of a fractured bone affected by caries. In its early days it was so

frequently followed by excessive infection that it was employed only in the worst cases. When it did succeed in bringing about consolidation it was only after many months and sometimes several years. It is when we compare such results with those obtained at the present time that we realize fully the advances that have been made in the treatment of this always serious condition. The great importance of the whole subject of fractures, to the physician, hinges largely upon the possibilities arising from the occurrence of pseudarthrosis. Because of the frightful mortality and the delayed convalescence and consolidation following the employment of this method of treatment before the introduction of antisepsis, the non-operative and minor operative methods of cure found their greatest favor and attained their highest development. Friction by rubbing the ends of the fragments together, ambulatory splints, injection of stimulating substances, perforation of the bone, pinning the fragments together with ivory pegs, and many other such methods of treatment were the products of that period. The non-operative were the methods of choice, and open operation the exception. In well-established cases the reverse is true to-day. That the question of the best treatment for ununited fracture has not yet been settled is shown by the numerous methods still in use. In the stage of delayed union pseudarthrosis is so common, and the results of early correction of errors in treatment, particularly by the application of a good immobilizing dressing, and direct irritation of the fragments by rubbing them against each other soon afterward, have been so successful that these measures are almost universally employed. Advanced cases, while very serious and important, are relatively so rare that no single surgeon has had an extended experience in their treatment. The weight of authority, it is true, is in favor of resection and fixation of the fragments, under thorough antiseptic technique; but there is still considerable difference of opinion as to the best means of fixation.

Fixation by Wire.—The earliest known attempts to obtain direct fixation of the fragments were made with wire, either as a suture passed through perforations in the ends of the bone, or as a ligature encircling the two fragments of an oblique fracture. The first use of the wire suture in the treatment of pseudarthrosis was made by Kearney Rodgers, of New York, in 1826. Horeau had employed wire for a similar purpose in 1805, but he surrounded and drew the fragments together with the wire as a ligature. Before the time of Listerism, the tendency was to bring the ends of the wire out of the wound, that it might be more easily removed later. At the present time the policy is to permit the suture to remain buried.

Silver wire is generally preferred to any other for this operation, because of the supposed antiseptic qualities of silver, its considerable strength, and its ease of manipulation. Other materials have also been employed, such as catgut, kangaroo tendon, silk, and silkworm gut, but they have not met with

the same favor as the silver wire. After the ends of the fragments have been exposed by a free incision, holes are drilled in the bone, the wire is passed through the perforations in both fragments, its two ends are brought together, twisted, cut short, and the ends pressed firmly down to the bone. In very oblique fractures the wire is still sometimes used as a ligature, encircling both fragments, with or without grooving the surface of the bone to prevent slipping of the wire. It may be used as a double ligature, by passing a loop through a perforation made at right angles to the line of fracture and passing through both fragments. The loop is then cut, making two ligatures, with which the frag-

Fig. 111.—Ununited Fracture of the Right Femur After Operation. The skiagraph shows a broken wire suture and angular displacement of the fragments. (Skiagraphed by Dr. H. K. Pancoast.)

ments are held closely together by twisting the ends of the two ligatures, each including a half of the bone. Although the wire suture is probably more frequently employed than any other mechanical means of direct fixation, strong objections are made to it by many surgeons. The most important of these may be summarized briefly as follows: the practical impossibility of so twisting the wire as to obtain absolute fixation at the seat of fracture; the frequency with which the wire breaks (see Fig. 111), and this usually after the wound has been closed, so that it is easily overlooked; the tendency to softening of the bone, loosening of the suture, and sometimes necrosis, owing to the tension of

the suture; and the objection to leaving a buried, non-absorbable, foreign body in the tissues. In the smaller bones where the strain placed upon the suture is not great, the wire suture has its greatest value. It is almost universally used in the operative treatment of pseudarthrosis involving the patella, olecranon, clavicle, and lower jaw. The tendency to lateral displacement in fractures of the patella and olecranon is slight or absent; while in the clavicle and lower jaw bony union occurs more readily than in any of the long bones of the extremities. Bone ferrules, closely fitting the periphery and binding together both fragments, as well as ivory and metal plugs made to fit snugly into the medullary cavity of each fragment for the same purpose, have received a fair trial, but have not met with continued favor. They generally give imperfect fixation, and frequently are followed by infection and suppuration.

Fixation by Pegs, Nails, and Screws.—Ivory pegs, iron nails, and screws have been used to advantage when the fracture has been sufficiently oblique to permit the fragments to be firmly bound together. They are also available with the *Volkmann "step method"* of dovetailing the fragments (see Fig. 112). In this method a rectangular portion is removed from the corresponding surface of each fragment, with a suitable saw. Two holes slightly smaller than the pegs or screws are drilled through both fragments, which are then pinned or screwed firmly and closely together. A greater area of freshened bone surface is presented for approximation, and a more firm apposition provided by the interlocking of the irregular surfaces. While in favor with some surgeons, this method is not generally used. Some length of bone is always sacrificed. Allis, in a case of ununited fracture of the humerus, experienced considerable difficulty in sawing the fragments accurately, and in fitting them together found it practically impossible to prevent lateral sliding of one fragment on the other, the side of one fragment falling into the central concavity of the other. In oblique fractures of the tibia, after the removal of the intervening fibrous tissue and freshening of the fractured surfaces by the curette and chisel, the writer has several times observed the fragments very firmly held together by *gimlets* (see Fig. 113). The whole lower extremity could be lifted by the

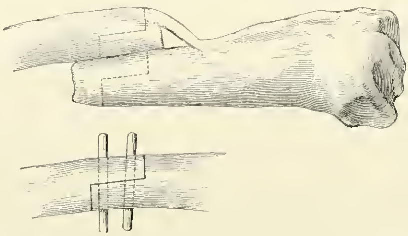


FIG. 112.—Volkmann's "Step Method" of Resection and Fixation of the Fragments. (von Bruns.)

heel, with absolutely no movement between the fragments, and later during the dressings without discomfort to the patient. This degree of fixation is maintained for a week or two, after which the softening which takes place about the gimlets renders such manipulations inadvisable. The gimlets, of course, protruded from the wound, which was closely sutured about them, permitting healing by first intention, except for the small openings left after the removal

Fig. 113.—Ununited Fracture of Both Bones of the Leg, with a Single Gimlet Giving Good Fixation. (Skiagraphed by Dr. H. K. Pancoast.)

of the gimlets. Firm union resulted in every case, and usually little or no infection. The wire suture could not produce the same degree of fixation, nor could the gimlets in a transverse fracture.

In 1892 J. William White employed in a case of pseudarthrosis of the humerus, a metallic plate an inch wide, with four holes, two for each fragment. These apertures in the plate were so arranged that the two for each fragment were three-eighths of an inch apart, and the inner one a half inch from the line of

fracture. After both ends of the bone had been freed from the surrounding tissues, they were sawed off transversely in sound bone, so that they came together accurately. Four holes were then bored in the bone with an awl slightly smaller than the screws, to correspond with the plate apertures. Four screws, the thread of which fitted that in the plate, were then inserted so that they held the plate and fragments firmly together (see Figs. 114 and 115). The plate was provided with a central handle, which was considered the least essential part of the apparatus, and was intended to steady it while the screws were being inserted. It, however, protruded from the wound and served also as a drain, the rest of the wound being closed. The fixation was very firm, the humerus moving as one piece with the same solidity as the bone on the opposite side. Firm union resulted and later the plates and screws were removed under ether.

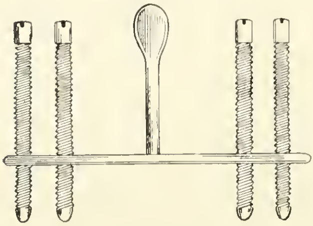


FIG. 114.—White's Plate for Fixation of Ununited Fracture After Resection.

Similar plates, without the central handle and with screws which do not project beyond the plates, may be employed. The wound may then be closed completely. This is considered an advantage by some surgeons, since it does not expose the seat of fracture to the risk of infection from the skin surface. As with White's plates, a second operation is usually necessary for the removal of the plates and screws.

The best reported results, following operation for ununited fracture, with which the writer is familiar, were obtained with Parkhill's modification of the plates and screws.* This apparatus was employed in 10 cases of delayed union or ununited fracture, 2 of vicious union with refracture, and 1 of compound fracture. Firm union resulted in every case, and in all except the compound fracture the time required was from five to eight weeks according to the size of the bone involved. In the compound fracture ten weeks were necessary. Healing by first intention occurred in 11 cases, and moderate infection in 2. Besides the firm fixation provided, the essential advantage of this apparatus is due to the fact that nothing is left in the wound except the screws, which are easily removed, and leave only small openings that heal rapidly. A second operation for the removal of the apparatus is, therefore, unnecessary. It has the additional advantage that the same firm fixation is provided whether the fracture is transverse or oblique. Parkhill describes the apparatus (see Figs. 116, 117, 118, and 119) and the operation

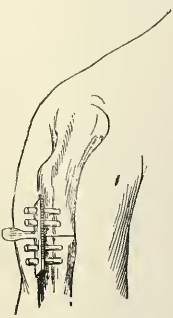


FIG. 115.—Diagram of White's Plate in Position.

*Parkhill: Annals of Surgery, 1898.

as follows: "It (the apparatus) consists essentially of four shafts, each with a thread cut on the lower end and also one near the upper end. The extreme upper end is made square so that the shaft may be governed by a clock key. Two sets of curved wing plates are attached to these shafts, the longer pair

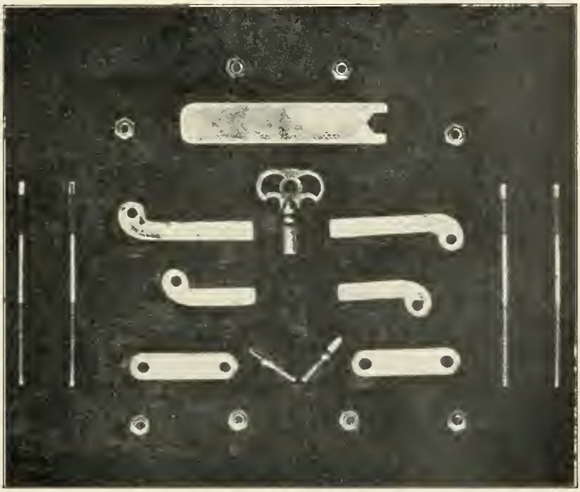


FIG. 116.—Separate Pieces of the Clamp. (Parkhill.)

corresponding to the outer ones, and the shorter pair to the inner. Each wing plate is fixed to its shaft by two nuts running upon the upper thread, one above the plate and the other below, for accuracy of adjustment. When in position one wing plate overlies the other in each half of the instrument,

FIG. 117.—Side View of Clamp After it Had Been Applied to the Fractured Tibia. (Parkhill.)

and when clamped the pair lie side by side. They are fastened together by a steel clamp with a screw in each end. These screws and shafts are controlled by the same clock key, and the nuts by a small wrench. Any method of resection of the bony fragments which may be found desirable in the particular

ease may be used. The transverse is probably the most easy of execution and generally the most desirable. The periosteum may or may not be separated from the fragments. In the forearm and in the leg, if one bone is intact while its fellow demands operation, it should be shortened to a corresponding degree and clamped in a similar manner. Each fragment is drilled trans-

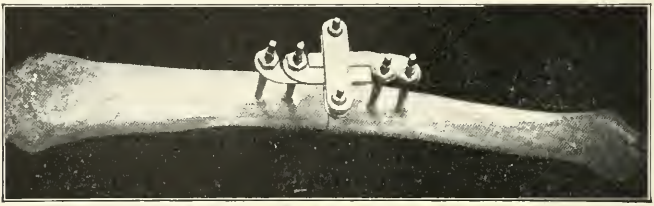


Fig. 118.—Top View of Clamp in Position. (Parkhill.)

versely to the long axis of the bone, and a small steel pin is thrust into the first hole while the second is being drilled, in order that they may be made parallel. The distance these holes should be from each other and from the ends of the fragments should be determined by the bone under operation and the size of the clamp to be used, of which there are three. The drill selected should

Fig. 119.—Clamp Ready for Removal at First Dressing, at the End of Six Weeks. (Parkhill.)

be a trifle smaller than the shaft of the instrument, in order that the threads may take a firm hold on the bone. The shafts are screwed in place by means of the clock key. This is accomplished more rapidly by means of the clock-key attachment fitted to a Langenbeck brace. The shafts being in place, their corresponding wing plates are adjusted and fixed by means of their nuts.

While the fragments are held in accurate apposition the wing plates are clamped together. The instrument is long enough to project through the soft tissues in order to allow the accurate suturing of the wound between the shafts and also for the interposition of a dressing. When possible the wound should be closed without drainage. The part operated on should be enclosed in a fixed dressing of plaster of Paris or something of a similar nature. The instrument should be removed in from four to eight weeks, depending on the bone operated on and the conditions of the particular case."

Fixation by External Splints.—In ununited fracture of the long bones Treves dispenses entirely with direct mechanical fixation of the fragments, his objections being made, specifically, against the use of the wire suture. He depends upon external dressings for immobilization and apposition, and also makes extension, for some time preceding the operation, to correct the shortening as far as possible. He is careful during the operation so to shape the fractured surfaces that accurate apposition is provided, but he believes that the success of the operation depends more on the completeness of the arrangements that are made for keeping the fragments in position after the operation than upon a careful operation itself. The necessity for careful adjustment of the fragments and infinite and continued care in the after-treatment is so urgent that, in dealing with an ununited fracture of the femur, he considers it best to operate on the bed which the patient will occupy throughout the whole treatment. Such anxiety in the after-treatment of a fracture which has already shown a disinclination to unite, indicates, in the writer's opinion, the necessity of a fixation apparatus applied directly to the bone; and the excellent results obtained from the use of the Parkhill instrument should make its use preferable to a resort simply to external splints. It may be advisable where the fragments show a tendency to easy and accurate apposition without mechanical aid; but, even in such a case, there may be an unexpected tendency to displacement from contraction of the muscles and the restlessness of the patient when he recovers from the anæsthetic, while the stimulating effect of the screws probably has considerable influence in promoting union.

Unusual difficulties sometimes arise from the atrophied ends of the bones, and from the fibro-cartilaginous covering of the fragments; while in other cases caries and necrosis have so destroyed the bone as to render the removal of a considerable portion of one or both fragments necessary, and the opportunities for union slight. In the latter cases it will usually be best at first to direct all efforts toward eradicating the inflammatory tissue and obtaining solid healing before attempting to unite the fragments.

In some cases *transplantation of bone* has been successful in filling the gap between widely separated fragments. The transplanted portion should be taken from one or both fragments, the periosteum and the attachments of the surrounding muscles being preserved wherever possible, and the fractured

surfaces being previously freshened for approximation with the transplanted bone. Fowler quotes Macewen as having succeeded in restoring the entire shaft of the humerus by successive transplantations of bone. He transferred the bone in the first operation directly from a case in which he performed a cuneiform osteotomy for genu valgum, and repeated the operation on two subsequent occasions. The final result furnished the boy with a humerus, which for all practical purposes was as functionally perfect as its fellow.

In very rare cases *amputation* may be justified as a last resort. A failure to provide a useful limb after a reasonably persistent trial of the various methods of treatment adapted to the stage of the failure and the bone involved will be exceedingly rare. The limb may, however, finally become a burden to the patient, especially in the lower extremity, and, from widespread necrosis or absorption, may become a flail-like appendage, when an artificial limb would be more satisfactory.

In addition to whatever local treatment is employed, the general health of the patient should always receive careful attention, and more particularly if the delay in union is protracted. Good hygiene and nutritious food are of much value, and the administration of drugs, such as iron, will often be necessary. Probably no drugs have any specific effect on the formation of bone. When operation is performed and union results in from five to six weeks, little or no advantage can be taken of open-air treatment. But when non-operative treatment is employed and many weeks or months are required for union, the patient should be advised to spend as much time as possible in the open air and sunshine. When the lower extremity is involved this advantage can usually be obtained by the use of a plaster cast or a Smith walking apparatus and crutches, and even when these are not advisable a wheeled chair will often enable the patient to avoid the depressing effect of long confinement.

PSEUDARTHROSIS IN CHILDREN.

The rarity of ununited fracture in children has already been referred to. Power* collected seventy-two cases, occurring in children under ten years of age. The bulk of these were in the older children, occurring either as the result of accident in the usual manner or of osteotomy or other operation performed for the relief of deformity. Cases of compound fracture, where possible, were excluded, as the pathology of these differed from the others. The frequency in the various bones differed markedly from that observed in adults. Of 70 cases, 6 were in the clavicle, 7 in the humerus, 12 in the femur, and 45 in the leg, one or both bones being involved. None occurred in the forearm.

The results of treatment were also striking. Bony union occurred in only

* D'Arcy Power, in Medico-Chirurgical Transactions, vol. lxxv.

21 cases, and of these 9 appeared to be examples of delayed union rather than of ununited fracture. In 4 improvement was noted, *i.e.*, the fibrous union became firmer; and in 45 there was no improvement. Sir James Paget considered that the measures suitable for pseudarthrosis in adults are entirely useless in children. Power's investigations confirm this view. Two cases reported by Southam are also confirmatory. Both involved the tibia and fibula, one in a girl seven years old and the other in a boy six years old. In the first, during four and a half years various methods of treatment were tried, including careful splinting for three weeks following the accident, and a plaster-of-Paris cast for one month afterward; repeated reapplications of the cast for the following fourteen months; "hammering"; exposure and resection of the ends of the bone; later wiring of the fragments; and finally a leather splint fitted to the leg. Bony union was not obtained. The second case resulted from an operation for the correction of a curvature. Two subsequent osteoplastic operations (bone-grafting) were performed, both resulting in fibrous union. Amputation was finally performed.

Power emphasizes the necessity of securing, by every means in our ability, immediate bony union after fractures in children, it being borne in mind that, if this process fail, the little patient will in all probability be a cripple for life.

PSEUDARTHROSIS IN SPECIAL BONES.

Pseudarthrosis in the long bones of the extremities occurs most commonly in the middle of the shafts of the humerus and femur, respectively, although fractures are most frequent in the forearm and leg, especially near the wrist and ankle. It is rare in other than the long bones, except the lower jaw, where it cannot be said to be common, though of sufficient frequency and gravity to deserve special mention. In the patella and olecranon it is almost constant after fractures, but as the functional results are all that can be expected, in the ordinary case, from non-operative treatment, it is not generally regarded as a failure of union. Owing to the strong tendency of the quadriceps and triceps muscles, respectively, to separate the fragments, only operative treatment could avoid it.

Statistics tend to show that this condition is more common in the humerus than in any other bone, although this is not without question. Agnew collected 685 cases of pseudarthrosis, of which 226 were in the humerus, 37 in both the radius and ulna, 23 in the radius alone, 16 in the ulna alone, 166 in the femur, 105 in both the tibia and fibula, 84 in the tibia alone, 2 in the fibula alone, 16 in the lower jaw, 6 in the patella, 1 in the clavicle, 1 in the scapula, 1 in the metacarpus, and 1 in the eighth rib. Norris collected 150 cases, of which 48 involved the femur, 33 the leg, 48 the humerus, 19 the forearm, and 2 the lower

jaw. In von Bruns' statistics there were 1,274 cases of pseudarthrosis, 376 occurring in the humerus. Of 681 authentic cases, 226 were in the humerus, or 33 per cent, while the frequency of fractures of the humerus was only about 15 per cent (von Bergmann). Of 56 cases demonstrated at autopsy (von Bruns) 22 were in the femur, 18 in the humerus, 8 in the leg, and 8 in the forearm. Morris says that it occurs most frequently in the femur, leg, arm, forearm, lower jaw, clavicle, and ribs, respectively.

The greater frequency in the humerus and femur may be explained by the close adhesion to and the more complete envelopment of these bones by the surrounding muscles, and, therefore, the greater tendency to interposition of portions of muscle tissue between the fragments; the frequent obliquity of the line of fracture and overlapping of the fragments from the contraction of the powerful muscles associated; and the difficulties experienced in immobilizing the seat of fracture.

Humerus.—Ununited fracture is relatively rare in the upper and lower ends of the humerus. Of 167 cases in Agnew's statistics, grouped according to the part of the bone affected, 4 involved the surgical neck, 12 the upper third, 110 the middle third including its junctions with the upper and lower thirds, and 41 the lower third. In other words they were all, except four, in the shaft, and two-thirds involved the middle third. By the shaft is implied that portion of the humerus between the surgical neck, or the upper margin of the pectoralis major tendon above, and the base of the condyles below.

Of 49 fractures of the humerus, seen by Hamilton, 29 involved the shaft, and of these one died in a few days. Of the remaining 28, in 4 union had not resulted after six months; and, in many more, it was delayed beyond the usual time. Three of the 4 cases of non-union occurred near the middle of the shaft, and 1 near the condyles. On the other hand, of 65 fractures of the shaft of the femur, generally near the middle, in not one was union delayed beyond six months. He explains the greater frequency of non-union in the humerus as follows: During the treatment of fractures of the shaft of the humerus, the elbow, which is universally dressed in flexion at a right angle, becomes rigid, so that every attempt at motion in the elbow is transmitted to the seat of fracture. Moreover, the elbow being fixed by an angular splint, the weight of the forearm, encumbered by the splint and bandages, though supported by a sling, tends to fall downward, thus tilting forward the upper end of the lower fragment. Variations in the positions of the head and body, the frequent movements of the shoulder, the respiratory movements of the chest, and the tendency of the patient to relieve himself of fatigue by lifting the forearm with the opposite hand produce a frequency of movement at the seat of fracture that finds no parallel in fracture of the shaft of the femur. Stimson attaches greater importance to rotation of the lower fragment on the upper, the forearm acting as a lever. The intervention of muscle tissue between

the fragments has been frequently reported. It is probable that all three conditions are very important factors in the production of pseudarthrosis in this bone, and would go far to explain the great frequency here. Intervention of the musculo-spiral nerve between the fragments has also been reported frequently. Pressure upon the nerve by forcing the two fragments together will cause pain to be transmitted down the forearm and hand, showing that the nerve is caught at the seat of fracture.

In an *operation* for ununited fracture of the humerus, the incision is made on the outer side of the arm, because the most important vessels and nerves are on the inner side, and because the bone is most superficial externally (see Fig. 120). The structure in greatest danger from the incision and the manipu-

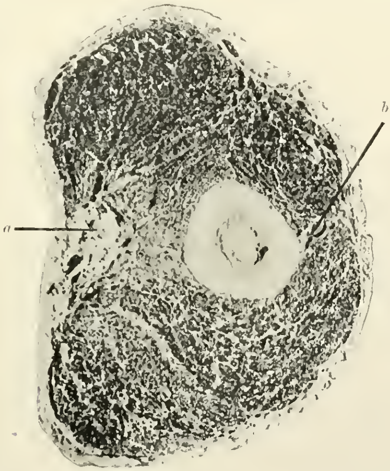


FIG. 120.—Transverse Section in the Middle of the Arm. (Original.) *a*, Brachial vessels, with median and ulnar nerves; *b*, musculo-spiral nerve.

lations necessary during the operation is the musculo-spiral nerve. It is also frequently injured in recent fractures of the middle of the shaft, either from the sharp fragments at the time of the fracture or from inclusion in the callus later. Bound closely to the bone by the fibres of the triceps muscle as it lies in its groove, it is in greater danger from the fragments than are the brachial vessels, the median and the ulnar nerves, which are further removed and more loosely attached, so that they more readily escape injury. Emerging from its groove in the humerus on the outer side at the level of the insertion of the deltoid and posterior to it, it passes downward on the outer side from the middle of the shaft to the elbow, where it divides into the radial and posterior interosseous nerves. In the operation for pseudarthrosis, additional care is necessary from the fact

that the nerve is often displaced and tied down by lymph, so that it may be not infrequently injured. Bigelow accidentally divided it twice, notwithstanding more than ordinary care, once completely and once leaving only a single fibre at one side. Later, the function of the paralyzed parts (supinators of the forearm and extensors of the carpus) returned in both. In a third case, partial paralysis ensued after an operation, the nerve having probably been

Fig. 121.—Ununited Fracture of the Humerus, with Parkhill's Plates and Screws in Position. (Skiagraphed by Dr. H. K. Pancoast.)

divided. Reference has already been made to the danger of injuring it in the violent movements necessary in producing friction by rubbing the fragments together in a case of delayed union. This danger is increased by its inclusion in the indurated mass about the seat of fracture.

Bones of the Forearm.—Of the 76 cases of pseudarthrosis involving these bones, found in Agnew's statistics, 37 affected both bones, 23 the radius

alone, and 16 the ulna. Of 22 cases involving both bones, 20 were in the middle third, 2 in the lower third, and none in the upper third. Of 13 cases in the radius alone, 8 were in the middle third and 5 in the lower third; and of 8 in the ulna 2 were in the upper third, 5 in the middle third, and 1 in the lower third.

As in fractures of the patella, fibrous union is the rule after those occurring in the *olecranon*. In rare cases attempts are made to obtain bony union by operation, when the functional results are sufficiently imperfect to demand relief. Dieffenbach, several times in old cases, divided the triceps tendon, brought the fragments together and rubbed them against each other, with considerable benefit in some cases. The *open operation* with wiring of the fragments as in the patella, is the treatment to be preferred.

Jacobson gives the *indications* for this operation as follow: "1. Where, in spite of careful treatment previously employed, the limb is weak and its usefulness seriously interfered with, especially where the occupation of the patient requires vigorous extension of the elbow. 2. Where such treatment has not been used, but the time for it has gone by. In either case the patient should be in good condition, and the younger the better."

The operation is essentially the same as that described for the same condition in the patella, except that a longitudinal incision is usually made over the olecranon and that a single suture of lighter silver wire is employed. The wound is closed without drainage, an antiseptic dressing and an anterior straight splint reaching from the shoulder to the palm are applied. As in the case of the patella it will sometimes be necessary to remove the wire suture later.

A group of fractures which in all probability will receive increased attention in the future are those involving the *head and neck of the radius*. The writer recently* investigated this subject and obtained sufficient skiagraphic evidence to prove that it is a comparatively frequent fracture. It is typical as to its mechanism and symptoms, and is of much importance owing to its relation to the elbow joint, the fracture of the head, which is frequently present even in fractures of the neck, being always intracapsular. The failure to recognize it is due to its peculiar obscurity. This can be amply explained by its deep situation, except posteriorly; by the close approximation of the radial head to the humerus and ulna, small portions of which are frequently broken off; and more particularly by the frequent close apposition of the fragments of the radial head, maintained by the orbicular ligament. Prat more recently† reported four new cases, and considered that it was remarkable how frequently these fractures have escaped recognition.

That non-union occurs with relatively great frequency is shown by the literature. Of 48 cases collected by the writer, death resulted from the severity of the associated injuries, immediately or soon after the accident, in 11

* University Medical Bulletin, Sept. and Oct., 1905.

† Revue d'Orthopédie, March, 1906.

cases, and in 15 more, amputation or excision was done so soon after the accident that there was not sufficient time to determine the kind of union of the fracture that would result. Of the remaining 22 cases, in 8 ununited fracture was present, while in 3 the detached fragment was described as a foreign body in the joint. In at least three more of the cases in which excision was performed, union was delayed beyond the time usually necessary for its completion; so that of 25 fractures delayed union or pseudarthrosis was present in 11, or 44 per cent. The actual frequency is probably much less, as the milder cases, which usually unite and are much more frequent than the severe and complicated, have very rarely been recognized, and therefore have not been reported. A brief review of the cases showing delayed or non-union will not be without value.

Malgaigne's* patient died fifty-five days after the occurrence of a dislocation of the head of the radius forward. Autopsy showed an incomplete fracture of the head of the radius, with no trace of reunion.

Gross† found a specimen in the dissecting-room in which a portion of the head of the radius had been chipped off and had become united to the contiguous border of the coronoid process.

Weichselbaum,‡ by accident, found in each elbow of a twenty-year-old, strong young soldier, who had died of dysentery, a free foreign body, and a corresponding loss of substance in that part of the radial head articulating with the ulna.

von Lesser§ excised a suppurating joint, some time after a heavy fall on the elbow, which had produced a wound that had been sutured. He found that the anterior and inner part of the radial head had been broken off, but still retained an attachment to the neck by a lamella of bone. There was a considerable cleft between the two fragments of the head.

Hueter‖ removed some time after the injury, by a free incision into the joint, two-thirds of the radial head, still attached to a strand of the capsule which had to be divided.

Pinner¶ refers to a specimen in the Pathological Institute of Freiburg, in which one-half of the radial head had been broken off and had remained attached to the capsule. The fractured surfaces, instead of uniting, had formed a false joint by eburnation.

Stimson,** two months after an injury to the elbow, excised the joint, which had suppurated. The anterior half of the radial head was separated from the rest of the head and from the shaft, with an irregular surface of fracture.

* "Traités des fract. et des luxat.," tome ii., p. 51.

† "System of Surgery," Philadelphia, 1859, p. 181.

‡ Virchows Archiv, Bd. lvii., p. 202.

§ Deutsche Zeitschrift für Chirurgie, Bd. iv., p. 202.

‖ Verhandl. der Deutschen Gesellschaft für Chirurgie, V. Kongress, 1876, p. 39.

¶ Zeitschrift für Chirurgie, 1884, xix., p. 74.

** "A Treatise on Fractures," 1883, p. 433.

Wainwright * operated on the elbow of a patient, more than thirteen weeks after a fall of twenty feet on the hand of the same side. The head of the radius was split into two nearly equal parts by a vertical cleft filled by fibrous tissue.

Cheyne,† seven weeks after a fall from a carriage, on the elbow, removed a loose fragment consisting of one-half of the head of the radius.

Stimson‡ operated on a man about six weeks after a fall from a truck, with his arm under him. The radial head was broken into several pieces, which were removed.

The prognosis of non-union in these fractures is not, of necessity, always bad. Weichselbaum discovered the condition in his case quite by accident. The patient had probably received the injury before he was called upon to pass

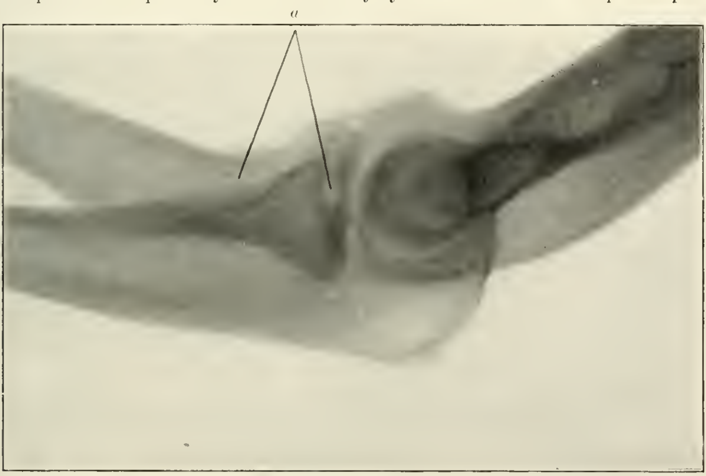


Fig. 122.—Ununited Fracture of the Head of the Radius, ten months after the injury was received. The symptoms were crepitus, constant pain, and limitation of movement. (Skiagraphed by Dr. H. K. Pancoast.) *a*, The two ends of the vertical line of fracture.

the examination as a recruit, so that the impairment of function must have been slight. This would be remarkable when we take into consideration the fact that both elbows were involved. The writer reported a case in which, six weeks after the accident, when union seemed to be present, there was detected for the first time a slight but decided crepitus over the radial head on rotation. On the same day and preceding the development of this symptom, the patient had received unusually vigorous treatment by the masseur. Coincidentally, and for the first and only time, there appeared considerable ecchymo-

* Transactions of the Clinical Society London, vol. xx., p. 73.

† British Medical Journal, March 7th, 1891.

‡ Annals of Surgery, 1898, vol. i., March and April.

sis about the elbow. The chief interest in this case consists in the fact that, although a slight grating can still be appreciated (sixteen months after the injury), the return of full function has been about as rapid and complete as in several other cases which the writer has had the opportunity of observing and which seemed to have united by bone in about three or four weeks.

That permanent impairment of function may result in some cases is certain.

Fig. 123.—Ununited Fracture of the Shaft of the Radius. (Skiagraphed by Dr. H. K. Pancoast.)

For instance, in Gross' and Pinner's cases, one fragment became ankylosed to the ulna, so that rotation must have been interfered with. In Wainwright's case, at the time of the operation, flexion and extension could be performed only through an angle of thirty degrees, while pronation and supination were reduced about one-half. The patient was quite unable to work. The deformity which is frequently present, and the possibilities of exuberant callus, threaten

the joint seriously. The writer is familiar with a case of typical vertical fracture of the head, which occurred about ten months ago. At that time there was no deformity, but crepitus was distinct. At the present time crepitus is still present and the patient is much annoyed by pain and limitation of extension and flexion. The skiagraph, taken a short time ago, still shows a line of fracture, but no displacement of the fragment (see Fig. 122).

The treatment of pseudarthrosis in these cases will depend chiefly upon the degree of disability present and to a certain extent upon the age of the patient. When the limitation of motion in the elbow seriously interferes with the usefulness of the limb, and the injury is confined to the head of the radius, excision of the detached fragment or of the head should be advised. The patient may, however, be advanced in years and may have become so accustomed to the impairment of function that he would prefer to continue

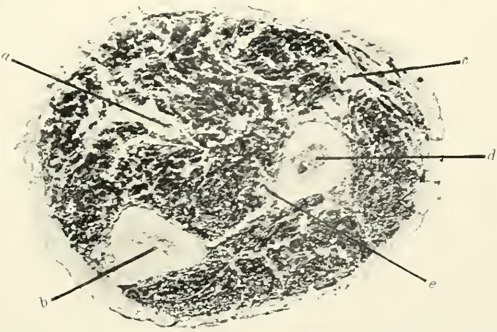


Fig. 124.—Transverse Section at Junction of the Upper and Middle Thirds of the Forearm (Original.) *a*, Ulnar vessels; *b*, ulna; *c*, radial vessels; *d*, radius; *e*, anterior interosseous vessels.

in that condition rather than to take the risk of an operation. Excision of the head in the stage of delayed union gave good results in the hands of Stimson and others, while Cheyne has also obtained excellent results from excision of the detached fragments.

The relative frequency of non-union in the *middle third* of the *shaft* of the radius becomes more evident when we take into consideration the infrequency of recent fractures in this portion. Only 10 out of 127 recent fractures of the radius seen by Hamilton occurred in this portion; and in the lower third, where the great majority of the fractures of this bone occur, he had never seen an example of non-union.

In approaching the shaft of either the radius or the ulna for operation on an ununited fracture, the incision should be made from the corresponding side of the forearm, and on both sides if both bones are involved (see Fig. 124). The same care should be observed to preserve unlimited the interosseous space

as in a recent fracture, to prevent the possibility of binding of the two bones together by callus. Because of the small size of the bones, light fixation devices are to be employed. Most surgeons prefer the wire suture, but in the writer's opinion light plates and screws are better, because they provide better fixation, require less disturbance of the fragments, and leave no foreign body permanently in the tissues. In some cases if one bone only is ununited and the

Fig. 125.—Ununited Fracture of Both Bones of the Forearm. Parkhill's plates and screws in the radius. (Skiagraphed by Dr. H. K. Pancoast.)

other united, it will be necessary that a corresponding portion of both should be removed and both treated in the same way. It will sometimes be found that mechanical fixation of one bone will provide sufficient immobilization of the other (see Fig. 125).

Femur.—Of 100 cases of pseudarthrosis of the femur in Agnew's tables, 8 were in the neck, 16 in the upper third, 64 in the middle third including its junction with the upper and lower third, and 12 in the lower third.

Until recent years little or nothing had been done to obtain union by operation in ununited fracture of the *neck* of the femur, which is very common. Patients suffering from this condition generally remain cripples for life. Gillette and Boeckmann* in 1898 reported three successful operations. A horseshoe-shaped flap consisting of the skin, superficial and deep fascia, with the base upward and covering the great trochanter, was made. The great trochanter was divided at its base and turned upward with its attached muscles, thus exposing the capsule of the joint. A longitudinal incision through the capsule exposed the line of fracture in the neck. The ends of the fragments were denuded, and a bone peg, that held the fragments together, was driven through the neck. The capsule was then stitched with catgut, and the great trochanter was replaced in its normal position and nailed with a small bone peg. The flap of skin and fascia was sutured in place, and a dressing and a silicate bandage were applied. Good union of the wound and solid bony union were obtained in all three cases, in from six to ten weeks, and ultimately there was a good functional result. R. H. Sayre obtained union in a similar case with the use of a gimlet. G. G. Davis employed, in two cases, an anterior incision for reaching the fractured surfaces. This passed vertically downward from the anterior superior spine of the ilium, and through the interspace between the tensor vaginæ femoris posteriorly, and the sartorius and rectus femoris anteriorly. A second incision was made directly over the great trochanter for the introduction of the fixation peg. Good results were obtained in both cases. Shaffer,† in two cases, succeeded in obtaining bony union with the use of a long Taylor hip splint, a belt of surcingle material about the pelvis to keep the fragments together, and a horsehair pad of crescentic shape over the great trochanter. The belt was firmly buckled on the opposite side of the pelvis. The limb was placed in abduction at an angle of about 20°, the insertions of the adductor muscles acting as a fulcrum and the shaft of the femur as a lever. The whole limb was placed on an inclined plane at an angle of about 135°. It was necessary later to pass a tourniquet over the padded belt better to control the latter. Bony union was obtained in one case in four months, and in the other in six months. In another case the patient was permitted to walk about with the Taylor splint, a high-soled shoe on the foot of the sound limb, and crutches. Bony union resulted after seven months. In still another case the method failed. None of the patients treated by these two methods was over forty-two years of age, so that they do not promise relief to the large majority of these cases which occur in older people.

Pseudarthrosis of the *shaft* of the femur is, next to that of the humerus, the most frequent, and of the two is the more serious. It generally affects young people and renders them almost helpless. Of the 166 cases in Agnew's tables, in 11 amputation was done, while of the 226 involving the humerus,

*Trans. Orthop. Ass'n, 1898, xi.

† N. York Med. Journ., 1897, lxvi.

only 7 were thus treated. After failure from the simpler methods of treatment, the open operation will be strongly indicated. The chief difficulties arise from the failure, frequently, to expose the fragments properly; from the greater opportunities for infection than in most other bones; and from the greater obstacles to keeping the fragments together and immobilized. These difficulties are considerably increased if the pseudarthrosis is well established, especially if other methods have been tried and have failed; where there has been little or no attempt at new bone formation, and more particularly if marked atrophy of the fragments exists or necrosis of a loose fragment from infection in a compound

Fig. 126.—Transverse Section in the Middle of the Thigh. (Original.) *a*, Deep femoral vessels; *b*, great sciatic nerve; *c*, superficial femoral vessels.

fracture, or from a comminuted fracture. The incision, which should be free, may be made anteriorly or externally, since the bone is nearest those surfaces, and all vessels and nerves are avoided (see Fig. 126). Parkhill made it anteriorly, while Treves advises the external incision. The seat of fracture being exposed and the fragments freed from the surrounding tissues, the periosteum is raised from the edges of the fragments and the fractured surfaces are freshened. This may be accomplished by pushing each fragment in turn out of the wound, and sawing off a thin slice from the end of each fragment if the fracture is trans-

verse, or, in the case of an oblique fracture with little displacement, by bending and separating the fragments sufficiently to permit curetting or chiselling away all fibrous tissue until healthy bleeding bone is reached in both fragments, care being taken to preserve the periosteum. A transverse saw cut would sacrifice too much length of bone in such a fracture. The fragments must be carefully protected by retractors or spatulæ during this stage of the operation. They are then brought together and accurately fitted to each other; the saw, curette, or chisel being used for this purpose. Firm fixation is then provided with some mechanical device, preferably with the largest size of the Parkhill plates. If the fracture is very oblique, two long screws or gimlets will answer the purpose. The wound is then closed, only the screws being left in the tissues. If the parts were not previously infected, and if careful antiseptic technique has been followed, an antiseptic dressing should be applied without drainage, and a plaster-of-Paris cast that will include the pelvis and the knee. If a drain is considered necessary a fenestra of sufficient size should be made in the cast, for future dressing of the wound.

Patella.—Although this bone is more frequently the seat of ununited fracture than any other in the body, efforts to obtain bony union have been the least frequent, for obvious reasons. Of the 685 cases of pseudarthrosis in Agnew's statistics, there were only six of the patella, those receiving treatment alone being included. Agnew says "the object aimed at in the treatment of these instances of non-union was doubtless to obtain a close ligamentous connection of the fragments." Hamilton was convinced that a fibrous union of less than one inch in length was quite as advantageous as a bony union and probably much stronger. He refers to a case in which, after fibrous union with a separation of a half inch, refracture occurred about a half inch above the first fracture and transversely. Of 127 cases which he collected, in 25 the new bond of union gave way completely, and in 2 more partially. A majority refused to reunite, even by fibrous tissue, and the few which did so unite were almost entirely confined to the examples in which the rupture occurred soon after the retentive apparatus was removed and in which the limb was immediately subjected to treatment.

The *indications for operation*, according to Lord Lister, are: in old cases (especially hospital patients) where the previous treatment had failed; in cases where, on account of the poor union, the limb had become useless, especially in a patient whose occupation required much walking or standing; in cases where the gait is helpless and requires much attention; or, finally, in cases where the patient has fallen frequently, threatening seriously a fracture of the opposite patella.

The increasing tendency among surgeons to do the open operation for recent fracture of the patella illustrates the present degree of confidence in modern antiseptic technique. It should be borne in mind that the knee joint must be

opened freely, and that the occurrence of infection exposes the patient to the danger of permanent impairment of function and to the risk that he will lose this limb or his life. The operation, therefore, demands unusual precautions as to cleanliness, and should be accompanied by as little unnecessary trauma to the tissues as possible. Longitudinal and transverse incisions have been employed, but, in order to expose properly the seat of fracture, they must pass over the most prominent part of the knee, and the scar, therefore, must be exposed to much pressure afterward. For this reason the curved incision from side to side will be preferable. If the curve be carried above the patella there will be no pressure on the scar in kneeling, and if a refracture occurs there will be little danger of opening the joint, as is likely to be the case when a straight transverse incision over the line of fracture has been employed. The flap thus made, including the skin and fascia only, is turned downward, freely exposing the fragments. The difficulties in freshening the fractured surfaces and accurately approximating them are considerably greater than in a recent fracture. The fragments will be surrounded by and adherent to the old cicatricial tissue. The lower fragment is sometimes very small, and the fractured surfaces of both fragments may be much atrophied. All fibrous tissue intervening must be thoroughly removed by the curette and chisel, or by a narrow-bladed saw, while an assistant steadies the fragment with a lion-jawed forceps. Care is necessary to prevent the débris from entering the knee joint, where it later may give rise to much irritation; and the soft tissues must be protected by retractors from injury by the instruments. Two holes are now made in each fragment with a drill, about an inch apart, from the anterior surface of the fragment obliquely to the fractured surface, where the drill should emerge above the cartilage, so that the suture will not enter the joint. A silver-wire mattress suture is then introduced through the bone perforations. It is made to pass toward the fractured surface of one fragment and out through the corresponding perforation in the other fragment. It is then passed back through the two corresponding holes on the other side of the bone, so that the two ends emerge from the two holes of one fragment. They are then given two or three twists, cut short, and pressed firmly down to the bone, so as not to project under the skin and later give trouble from pressure. It was formerly considered preferable to remove the suture after union was complete, but in recent fractures, where this operation is frequently performed, the wire rarely gives trouble and is usually not removed. A. C. Wood* avoids pressure on the twisted ends of the wire by using two lateral wire sutures. He introduces the drill from the lateral aspect of the circumference of each fragment, bringing it out on the fractured surface, so that when the two fragments are brought together the twisted ends are at the side of the patella where there is no pressure and where they are far removed from the incision. The wound is

* Proc. Phil. Co. Med. Soc., Nov. 29th, 1905.

closed without drainage, an antiseptic dressing applied, and the limb elevated with a posterior splint, as in the ordinary non-operative treatment of recent fracture of the patella.

Bones of the Leg.—Of 64 cases of ununited fracture involving both the tibia and the fibula, in Agnew's tables, 38 occurred in the middle third including its junctions with the upper and lower thirds, and 26 in the lower third. Of 48 involving the tibia alone, 5 were in the upper third, 27 in the middle third, and 16 in the lower third. The fibula was the seat of pseudarthrosis in only 2 cases, the lower third being involved in both.

The frequency of ununited fractures in these bones may be accounted for by the frequency of compound fractures, with loss of bone substance and

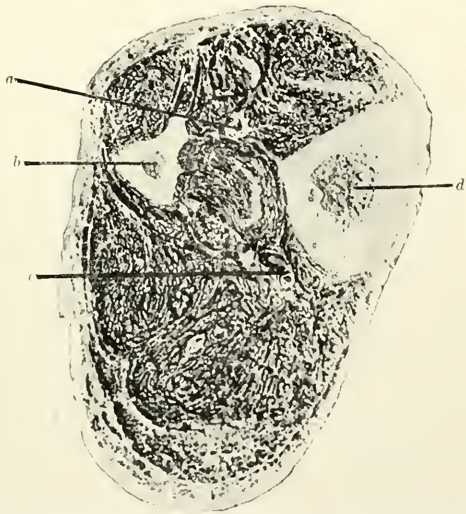


Fig. 127.—Transverse Section in the Middle of the Leg. (Original.) *a*, Anterior interosseous vessels; *b*, fibula; *c*, posterior interosseous vessels; *d*, tibia.

necrosis; by the usual obliquity of the lines of fracture in both bones, especially in the tibia, and the powerful muscles tending to produce overriding of the fragments; and by the frequency of serious complications, often rendering the application of suitable fixation dressings difficult and sometimes impossible. Injury of the nutrient artery may also be a cause.

Owing to the subcutaneous positions of the antero-internal surface of the tibia and the external surface of the fibula in its lower portion, the incisions for exposing the seats of fracture should be made on these surfaces (see Fig. 127). The skiagraph will aid materially in determining the exact position and the

proper length of the incision in any case. If it becomes necessary to remove a considerable portion of the tibia a corresponding portion of the fibula, whether it be the seat of pseudarthrosis or not, should be removed also, to permit of a proper approximation of the tibial fragments. In such cases, however, much deliberation should be exercised, otherwise impairment of motion or failure of union may follow. It is necessary to be very careful not to remove too much of the fibula,—an errror which it is more difficult to avoid than one would at first suppose. If too much of this bone is excised, a portion of one fragment

Fig. 128.—Ununited Fracture of the Lower Jaw, with Necrosis. (Skiagraphed by Dr. H. K. Pancoast.)

may be separated and transplanted *en masse*, or, better, in fragments, in the gap. The curette or chisel, or both, will usually be preferable to the saw in preparing the ends of the fragments for approximation, because of the frequent obliquity of the line of fracture. In some cases in which the displacement is slight (see Fig. 113) it may not be necessary to detach the fragments from the surrounding tissue, bending of the limb being sufficient to expose the fractured surfaces for the use of the curette or chisel. When the ends of the bone are properly prepared, they are to be accurately apposed to each other and immobilized, preferably by plates and screws. Where the apposition is good and there is no tendency to displacement, external splints may

be relied on for immobilization. Since, in these cases, an inability to produce the necessary callus and bony union has already been shown, it will be best, in most instances, to obtain the stimulating effect of the temporary presence, at the seat of fracture, of the screws.

Lower Jaw.—Of the 16 cases of delayed union and ununited fracture in Agnew's statistics, 11 involved the body, 1 the angle, and in 4 the location was not given. Thirteen were cured, 1 was relieved, and 2 died, 1 developing pyaemia and the other virulent variola.

It is remarkable that failure of union is not more common in a bone so difficult to immobilize thoroughly, and in which fracture is so commonly compound. Not only is non-union comparatively rare, but union is usually rapid.

In cases which have failed to unite (Fig. 128), consolidation has been obtained by prolonged immobilization, both with external and with interdental splints, so that usually early operation is not indicated. Friction by rubbing the fragments together and subcutaneous drilling have also been successful. In well-established cases it will be best to expose and freshen the ends of the bone by the curette and chisel, and to immobilize them by wire sutures and external splints. In some cases the operation can be carried out best from within the mouth, and in others an external incision will be necessary.

INFLAMMATORY AFFECTIONS OF BONE.

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INFLAMMATORY processes in bone in all essential points are similar to such processes occurring in the soft tissues or organs of the body, but the phenomena are so modified and restricted by the peculiar physical character of bone tissue as to be almost unrecognizable except by inference. The classic signs of inflammation—redness, swelling, heat, and pain—as described by Celsus, are unquestionably present, but are not easily appreciable to the senses of the surgeon owing to the depth of the inflamed structure from the surface of the body. As in the case of inflammation of the soft parts, the causes of inflammation in bone may be of three kinds: mechanical or physical, as in the case of fractures and injuries by direct violence; or organized, as in the case of inflammatory processes due to micro-organisms (the tubercle bacillus, the staphylococcus, or the streptococcus); or functional or nervous, as in the bone manifestations of rheumatoid arthritis and locomotor ataxia. It is in the defensive reaction against such various injuries that the inflammatory processes in bone take place, and the economic intention of such processes is a beneficent one and inclines toward the protection of the body as a whole and toward the recovery and restoration to health of the parts locally affected. It is mainly from reasoning by analogy that it is known that the microscopic manifestations of inflammation are similar in bone to those in the soft parts, but it is perfectly certain that the initial injury, whether mechanical, thermal, chemical, or toxic, is followed by the vascular phenomena of acceleration of blood stream succeeded by retardation; the sluggish movement of the stream passing into oscillation, then stasis, and thrombosis. In the mean time the injured vessel walls have permitted the leakage of the blood plasma and serum, the migration of white blood corpuscles, and, in cases of intense inflammation, the escape bodily of red blood corpuscles into the tissues immediately surrounding the minute blood-vessels in the inflamed area. The functional activity of the inflamed part is seriously altered and the manifestations of positive and negative chemiotaxis, as described by Metchnikoff, occur in bone precisely as they do in other parts of the body.

As in the soft tissues of the body, the results of inflammatory action in bone are of very many different characters. In mild cases, or where the causative agent ceases to act, the result may be a complete recovery and restoration of the affected part to its original form; or, as in the case of fractures, there may

be brought about a physiological welding of the broken bones in a manner which could not possibly have been produced without the inflammatory manifestations. On the other hand, there may be a complete alteration of the structure and consistency of the bone by the removal of normal tissue and the substitution of the products of inflammation in the shape either of scar tissue, which takes the form of condensed bone, or of abscess formation. In cases in which the causative agents are of an extremely virulent nature, there may be a total death of the part. Even a mechanical cause may be so severe in action as totally to deprive a portion of bone of its vitality; or, in the inflammatory processes such as take place in osteomyelitis, the germ may produce such a profound effect upon the circulation as totally to shut off the blood supply to a certain area of bone, thus bringing about a complete necrosis or sloughing of a portion or the whole of the shaft of the bone.

But while, as pointed out above, all essential features of inflammation are present in bone, the mechanical problem presented by the presence of such physical construction as the compact tissue, the cancellous tissue, the medulla, or even the periosteum of the bone, furnishes such a series of modifications in the inflammatory processes as they affect various parts that a separate description of certain of these processes would seem to be indicated in order to make clear the use of various terms that will necessarily be employed in the description of different inflammatory diseases of bone.

Nomenclature.—In the broad sense, all inflammatory processes in bone may be comprised under the terms: Periostitis, or inflammation of the periosteum; osteitis, or inflammation of the bone substance, whether compact or cancellous; and osteomyelitis, inflammation of the medulla of the bone; but so various are the different clinical and pathological phenomena, and so widely divergent are the results of the different characters which these inflammations assume, that it becomes necessary to treat each condition under a different heading. The designations used to distinguish the different forms of the inflammatory diseases of bone are derived in some cases from the character of the causative agent, as in tuberculous and syphilitic diseases; in some cases from a prominent clinical feature of the disease, as, for example, in acute necrosis, acute epiphysitis; and, finally, in other cases from some characteristic physical result of the disease, as in osteoplastic periostitis, osteosclerosis, etc. It must also be distinctly understood that, although for purposes of description the inflammatory diseases of one component of the bone may be treated separately from the other components, it is rare indeed that the periosteum, for example, is inflamed without the affection reaching the bone beneath, and still more rare for inflammation of the medulla to occur without accompanying inflammation both of the osseous tissue proper and of the periosteum.

INFLAMMATORY DISEASES OF THE PERIOSTEUM.

Structure and Character of the Periosteum.—The important membrane which covers the bones is endowed in health with great vitality, and with a resisting power of a very high degree of efficiency. Even under circumstances of violent injury or virulent inflammation the periosteum seldom sloughs, and, even should sloughing occur, the membrane seldom perishes *en masse*, sufficient shreds generally surviving to furnish wonderful results in the way of reproduction of new bone. Even into adult life and advanced years the periosteum appears to retain much of its primal embryonic power, and, indeed, this power seems to be stimulated under irritation, whether physical or chemical. Doubtless these extraordinary economic powers are due to a large extent to the high degree of vascularity of this membrane and to the vigor and vitality of the osteoblasts which line its inner surface and lie adjacent to the bone tissue.

In structure the periosteum consists largely of fibrous tissue, the outer layer being composed principally of white fibrous tissue, and affording a nidus for the larger vessels, while the inner layer furnishes a medium for the distribution of the smaller vessels to the osseous tissue, and contains numerous yellow elastic fibres which intermingle with the white fibrous structure. The inner layer is also lined by a fairly continuous stratum of osteoblasts. In adults, and in a condition of health, these cells are flattened for the most part, dormant and quiescent, containing only a small amount of granular protoplasm around their nuclei. Under the stimulation of irritation, however, whether of physical character, as in fractures and traumatic injuries, or of toxic character, as in the infective inflammations, these cells become swollen, granular, and angular in shape; their resisting power seems to be augmented, and their reproductive power stimulated and promoted. As above stated, the vessels of the periosteum are numerous and large particularly in the case of the long bones. From the under surface of the periosteum they penetrate the numerous open mouths of the Haversian canals, being accompanied by minute nerves which are also distributed from the periosteum. On lifting up the periosteum gently from the bone and peering into the angle which it is thus made to form with the surface of the bone, one can frequently see these small vessels as they are stretched and lifted out of their corresponding canals by the separating process. In cases of suppuration occurring under the periosteum, frequently these vessels may be seen to be completely thrombosed, thus shutting off entirely the supply of nutriment to the bone beneath, and leading frequently to necrosis. It will be pointed out later, however, that destruction of these vessels is not necessarily followed by death of the bone, because there is a tolerably liberal anastomosis between the vessels derived from the periosteum and those distributed from the nutrient artery of the bone.

The periosteum varies in thickness and in the other qualities above described very considerably in different parts of the body. In the long bones, such as the femur and humerus, its bulk comports with the weight and importance of the bone which it covers, whereas in the case of the flat bones of the skull and face it is very much thinner and possessed of much less reproductive power in cases of injury or disease. In the short bones of the carpus and tarsus, and in the vertebræ, it is so incorporated in places with the sourrounding ligaments as to be indistinguishable as a distinct entity.

Acute or Subacute Non-suppurative Periostitis.

This process, when it displays the character of a non-suppurative disease, is somewhat rare. There are, however, instances of an affection of the periosteum presenting the symptoms of intense pain, swelling, and thickening of this membrane, with some redness of the skin over the part if the affected bone is situated close to the surface. The amount of fever present is usually insignificant, and may be accompanied by a slight rise of pulse rate. The cause is usually traumatic, such as a blow or crush which presses the periosteum against the bone beneath. Usually the extent of the disease is confined to the immediate seat of injury. Ollier has described a condition which he designates *albuminous periostitis*, in which a fluid of a serous character, highly charged with albumin, collects under the affected membrane. This form, apparently, often passes on into the suppurative type of periostitis, and under such circumstances doubtless the inflamed tissues are infected with pyogenic germs.

Sore or "Bucked" Shins in Young Horses.—From the point of view of comparative pathology it is extremely interesting to note in this connection that veterinarians describe a disease which occurs in young horses as a result of severe training on a hard track, which seems to be identical with the "albuminous periostitis" of Ollier, and to which both veterinary surgeons and the laity apply the term "sore or bucked shins." The cause appears to be the violent concussion to which the metacarpal bones are subjected in bursts of speed over a hard, unyielding surface. Such concussion appears to spring the bones in such a way as to bring about a partial separation of the unyielding, inelastic periosteum covering them. The result is that a subperiosteal exudate of serous fluid, frequently tinged with blood, collects and raises the membrane away from the bone beneath. Should this fluid become infected with pyogenic organisms, suppuration will occur; and so great is the separation of periosteum in some instances that a necrosis of the bone beneath may take place. The occurrence of suppuration and necrosis in these cases is very rare, since the periostitis usually becomes osteoplastic in form and results in the deposit of irregular layers and nodules of new-formed bone, which some trainers believe adds to the strength and durability of the limb. The development of "splints" in young horses is also usaully due to a traumatism exciting periostitis and osteitis, which result in the formation of a nodule of new bone, usually upon the inner and upper aspects of the foreleg.

Symptoms.—The degree of pain, tenderness, swelling, and fever will bear a direct proportion to the intensity and extent of the inflamed area. The pain is noticeably worse at night, and the tenderness is usually very well marked, even when the pain may not be severe. Swelling is generally to be recognized after the lapse of the first twenty-four or forty-eight hours, but redness of the surface is not common unless the bone is very superficial or the process has become septic and is passing on to the suppurative type.

Prognosis.—Recovery within a few days or weeks is the rule. Sometimes a thickening, due to the deposit of new bone by the inflamed periosteum, persists. Occasionally the accretion may be permanent, but usually it becomes slowly absorbed and disappears entirely in the course of a few months. Should there occur a pyogenic infection of such an area of inflammation, suppuration and necrosis may result, but this happens rarely. As something very exceptional, there may be loss of vitality of a shell of bone without suppuration, as happened in the following case:

W. McM., a tennis player, sustained profound subcutaneous injury to the periosteum of the tibia through striking the shin against a board at the margin of the tennis court. A sharp attack of periostitis with great pain and tenderness followed, but without suppuration. A small, tender swelling, about three-quarters of an inch long, persisted after the pain and other inflammatory symptoms had subsided. Some ten weeks afterward, when this swelling was incised, a thin shell of bone, about the thickness of one's finger-nail, was discovered and removed. There was no suppuration, and the wound healed promptly.

Treatment.—Rest, in a recumbent position, with the affected part elevated, is the most essential element of the treatment of these mild inflammations. The application of moist heat is distinctly soothing. One or two leeches may be applied, preferably at some short distance above the inflamed area. The patient should be placed upon a spare diet, and the bowels should be freely purged. In severe cases, where the pain is very great, a subcutaneous incision through the periosteum will give great relief. This should be done with the same care, as regards asepsis, as would be exercised in an operation of greater magnitude. Cocaine anæsthesia will be sufficient, and the fine tenotome used should be entered at a distance of about half an inch from the edge of the swelling, passed between the periosteum and the skin to reach the opposite limit of the swelling, and then carried through the periosteum to the bone, so as to divide the former as the instrument is being withdrawn.

Chronic or Osteoplastic Non-suppurative Periostitis.

By the demands of the pathological processes of this disease it is essentially chronic in character. As above stated, sometimes the acute, non-suppurative form of periostitis becomes chronic, and the osteoplastic function of the perios-

teum, stimulated by the impulse of the chronic irritation, deposits somewhat irregular lamellæ or processes of new bone upon the surface of the parent bone (Fig. 129). It usually occurs as the result of slight, frequently repeated irritations of a mechanical character, or as the expression of a constitutional taint in young subjects, and Erichsen describes it as an exaggeration of the normal possibilities of growth in bone. Under the influence of such irritation, whether of mechanical or of constitutional character, the periosteum becomes swollen and thickened and much more vascular. The membrane is found to be easily

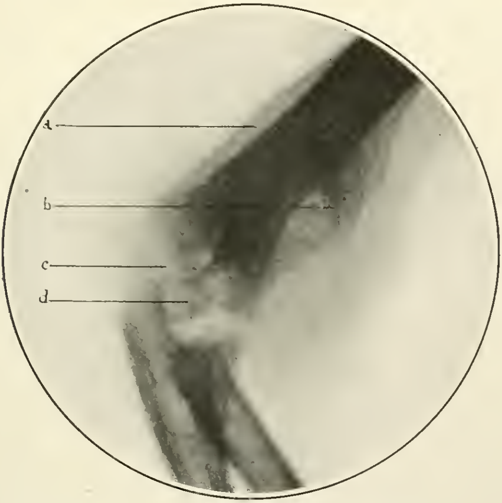


FIG. 129.—Skiagraph of a Case of Osteoplastic Periostitis Following Injury. *a*, Newly formed bone; *b*, a mass of bone forming in front of the lower end of the humerus from detached periosteum or in the substance of the brachialis anticus (myositis ossificans); *c*, the elbow joint; *d*, lower epiphysis of the humerus. (Skiagraph by Dr. S. Cummings, of Toronto.)

separated from the surface of the bone, and its under surface is studded with gritty particles of newly formed osseous tissue, the result of the activity of osteoblasts which are capable under such circumstances of developing latent embryonic activity. The bone at first deposited under these circumstances is of an immature and irregular character, and is roughly arranged in lamellæ or spicules and nodules of various shapes. This spongy, irregular bone, however, subsequently becomes organized into more or less distinct Haversian systems, and shrinks in bulk as it becomes more highly constructed.

Etiology.—As above mentioned, the condition may be a sequel of acute periostitis, or it may be a result of constitutional disease. The most common constitutional cause is syphilis, and in this disease thickenings of a permanent

character, called nodes, may develop on various bones, the most common being the tibia, the clavicle, and the bones of the forearm. In tuberculous disease also a certain amount of osteoplastic periostitis may occur around the margins of tuberculous processes of a more active and destructive character. In chronic rheumatoid arthritis, again, there may occur in the neighborhood of the joints osteophytic processes, buttresses and spurs which may completely lock the joints. Osteoplastic periostitis is also the most prominent characteristic of the curious, mysterious disease known as osteitis deformans. All these constitutional conditions, however, will be fully treated in the articles especially devoted to their consideration.

Treatment.—Usually the treatment for this condition is that of the constitutional disease of which it is an expression. Relief of the pain at night, which is so prominent a symptom, may sometimes be obtained from the use of iodide of potassium in full doses—say, 20–30 grains three times a day—or by the use of repeated small blisters over or near the seat of pain. In very severe cases an incision through the thickened periosteum from end to end of the swelling may be found advisable, and, if the inflammation extends into the bone beneath, the incision may be continued through the compact tissue to the medulla. This operation is known as *linear osteotomy*.

Acute Suppurative Periostitis.

Acute suppurative disease of the periosteum will be considered under the following headings:

(1) Suppurative disease occurring as a sequel or terminal result of the acute inflammation above described; (2) post-febrile periostitis, such as that following typhoid fever, scarlet fever, etc.

(1) *Suppurative Periostitis.*—When suppuration occurs as a terminal result of acute periostitis of traumatic origin it is due to the presence, at the seat of inflammation, of some of the pathogenic germs, especially the staphylococci or streptococci. The physiological resistance of the injured part is already depreciated by the injury sustained, and when the germs lodge the accumulation of inflammatory products affords a favorable nidus for their implantation and growth. The suppuration which results is usually confined within somewhat sharply defined limits and the periosteum is commonly perforated spontaneously so as to allow the escape of the pus into the surrounding areolar tissue before any great degree of separation of the membrane has taken place. It is indeed quite rare for such an inflammatory process to result in an extended separation of the periosteum, such as occurs in the disease to be described later under the heading of "Acute Osteomyelitis."

Symptoms.—The symptoms are those of the acute, non-suppurative variety of inflammation in an accentuated form. When suppuration occurs there will

be an elevation of temperature and pulse rate commensurate with the intensity and extent of the disease, with sometimes the occurrence of a chill or chilly sensations. Redness of the skin over the inflamed area, and œdema as revealed by pitting on pressure, will observed. The patient also experiences very much more pain, suffers from loss of sleep and failing appetite, and altogether displays a much more serious condition in the latter variety.

Treatment.—The only item to be added to the treatment already prescribed for the simple condition is to advise very prompt incision through the periosteum of the inflamed area. The incision should be quite free and should be made with precautions to avoid the introduction of any other germs than those already present. Great relief of all symptoms immediately follows upon the making of the incision, and usually the suppuration subsides very promptly. The periosteum falls back to its normal position, granulations spring up from the bone beneath, and recovery without necrosis is the rule. Occasionally, however, a thin, superficial layer of bone will perish, which greatly delays recovery, since perhaps there will be required for its separation a lapse of some weeks or possibly even months.

(2) *Post-febrile Periostitis.*—The diseases in which inflammation of the periosteum occurs as a sequel are principally typhoid fever, scarlet fever, measles, acute articular rheumatism, and pneumonia. Of these, typhoid fever is much the most common precursor of the condition. Sir James Paget has observed and commented upon some 70 cases of periostitis following typhoid fever, and in 1876 Dr. W. W. Keen of Philadelphia quoted 41 cases of disease following fevers, of which 37 were sequelæ of typhoid fever. In 1894 Dr. H. C. Parsons of Toronto fully discussed the subject and analyzed 6 cases which had occurred during that year in the Johns Hopkins Hospital. The typhoid bacillus in these cases appears to possess pyogenic properties and remains alive, though dormant, with great persistency in the osseous tissue. In 4 out of 6 cases which Parsons reported he obtained a pure culture of the Bacillus typhosus. In one of the other cases the staphylococcus was found in addition to the Bacillus typhosus. This germ may bring about the suppurative process in bone in the later stages of typhoid fever or during convalescence; or, on the contrary, it may lie dormant within the bone tissue for many months or even years. Nothnagel reported a case which occurred six years after a primary attack of fever, and Buschke reported the finding of living typhoid bacilli in the pus of bone lesions which developed forty-six years after the febrile attack. This persistence of the typhoid bacillus in bone without giving rise to symptoms is in harmony with what we know of its behavior in other organs. Duba reported its presence in the gall bladder seventeen years after the primary attack of typhoid fever. The bone lesions caused by this organism more frequently affect the periosteum than the medulla of bone, though numerous cases of what are known as "Brodie's abscess" appear to have owed their origin to its belated ravages. The symp-

toms associated with this condition develop slowly and usually give rise to a mild constitutional disturbance. Their clinical histories resemble rather those of tuberculous lesions than those of typical acute osteomyelitis. The resulting sequestra are usually small and superficial, and healing generally takes place somewhat tardily after their removal.

The pus from a typhoid bone lesion may be a source of danger to those associated with the case, either in the capacity of attendants or in that of dressers. In a case recently reported a man developed a suppurative osteitis some two years after an attack of typhoid fever. The pus from the bone lesion was found to contain typhoid bacilli, and, while the sinus was still discharging, the patient's wife, who had been accustomed to collect and burn the soiled dressings, developed typhoid fever and died. As there had been no other case of fever in the neighborhood, and no other possible source of infection could be traced, her illness and death were naturally attributed to infection from the discharging sinus.

Prognosis.—Not always does suppuration occur in this form of disease, but the disease may persist in a chronic, non-suppurating form for many months and ultimately undergo resolution and absorption. When suppuration does supervene, however, the case is likely to be an extremely chronic one, and instances of a duration amounting to four or even six years have been observed. Usually the pus accumulates under the periosteum, but occasionally the abscess forms in the medulla. This condition adds greatly to the gravity of the disease and calls for very much more heroic treatment.

Treatment.—A free incision, with a thorough scraping of the diseased area and a disinfection of the whole cavity, is called for. Watson Cheyne holds strongly that the germ is generally located in the medulla, and recommends that the medullary cavity should be opened up and scraped throughout the whole extent of the visible disease, even if it should involve the entire length of the shaft of the bone. The whole cavity should then be swabbed with pure carbolic acid, so as thoroughly to disinfect its surface. If care be taken to mop away all excess of fluid, or to flood the cavity with alcohol, there is no danger of carbolic-acid poisoning. The subsequent treatment of the resulting larger cavity is similar to that of large cavities occurring under other conditions, and the subject will be taken up under the heading of Treatment of Acute Infective Osteomyelitis.

OSTEITIS.

The occurrence of an inflammatory process of bone affecting either the compact tissue or the cancellous tissue, apart from a coincident periostitis and osteomyelitis, is practically unknown, but the phenomena of inflammation of

the dense portions of the bone are so diverse from inflammations in soft tissues that a description of the process merits separate consideration. It is quite evident that in dense bone there cannot occur the same degree of exudation of blood plasma and white blood corpuscles that is present in the soft tissues unless there also occur at the same time an absorptive process of the osseous tissue itself. A study of the minute anatomy of bone substance reveals the fact that the bulk of the bone is composed of what are known as Haversian systems, each system consisting of a concentric arrangement of lamellæ of bone around a Haversian canal. The interstices between these systems are filled in by incomplete units of the same character. In the interior of each canal are found usually an artery, an accompanying vein, and a nerve from the cerebro-spinal system. Between the various lamellæ also are lacunæ, which lodge the bone cells or corpuscles, and from which extend minute canaliculi which branch in various directions and communicate with similar minute canals from adjacent lacunæ. Moreover, processes of the bone corpuscles occupy these canals, so that the adjacent cells communicate with one another in all directions; for, after all, a bone corpuscle is simply a branched connective-tissue corpuscle. Through these lacunæ and canaliculi there flows a current of lymph which ministers to the nutrition of the cells and surrounding bone, and also promotes the removal of decomposed tissue. Near the periosteum the Haversian systems are less distinctly defined and the general tendency is toward an arrangement of lamellæ parallel with the surface, while toward the medulla the Haversian canals become large, are surrounded by a greater amount of cellular tissue, and gradually blend with the cancellous tissue in the interior without there being any sharply defined line of demarcation between them. From these considerations of the structural qualities of bone it is quite clear that the ordinary phenomena of an inflammatory process are necessarily greatly modified especially in compact bone tissue. For example, while exudation and migration of corpuscles certainly take place to a limited extent, there cannot be any such accumulation of these extravascular elements as to lead to an appreciable degree of swelling. Also, when such accumulation takes place to as great an extent as possible, since the dense bone cannot expand, the tendency is for the circulation in the vessels to be choked off; and thus, in a very acute type of inflammation, as will be seen when we come to speak of Acute Osteomyelitis, there may occur such an interference with nutrition as to lead to the death *en masse* of large areas of compact bone. This result, of course, represents a disastrous extremity, while, on the other hand, in minor degrees of inflammation the exudate may all be absorbed and the bone return to its normal condition. Between these two extremes, however, are two other very peculiar processes which prevail, respectively, in many different diseases of the bone. These two conditions are diametrically opposed to each other in their ultimate results, the one, Osteoporosis, leading to great wasting, thinning, and softening of the bone (rarefaction),

while the other, Osteosclerosis, leads to increase in bulk, and extreme condensation or hardening (osteosclerosis).

Osteoporosis, or Rarefying or Rarefactive Osteitis.

In rarefying osteitis, as the name implies, the general result is a diminution in the degree of density of the osseous tissue of the part affected. The Haversian canals become tunnelled, as it were, and considerably enlarged, so that many of them are visible to the naked eye. The space from which the bone has been absorbed becomes filled with embryonic tissue which appears as a pink granulation mass within the enlarged canals. The absorption of the bone and its replacement by such granulations appear to take place by a process of erosion of the osseous lamellæ. Irregular excavations, known as "Howship's lacunæ," occur in the portions of bone in which the rarefactive change is proceeding. In the granulation tissue occupying these excavations are found large, multinuclear, irregularly shaped cells called "osteoclasts." These cells constitute the attacking force upon the bone substance. Their nature is very peculiar. Their origin is not definitely known, nor is it known what ultimately becomes of them, but they are unquestionably endowed with the faculty of dissolving the bone salts. Whether this is accomplished by some power of secreting solvent acids, or by some other digestive or phagocytic function, is not known. At all events, it is quite certain that these cells perform during their limited period of existence a series of very effectual scattered attacks upon the osseous structure. If a portion of bone, which has been undergoing this process for some time, is macerated thoroughly and then washed out under a stream of water, the bone is found to present a condition of porosity such as that observed in a sponge or piece of coral. If the process persist for a sufficient length of time the whole of the osseous lamellæ may be absorbed, and the cancellous spaces fuse with one another so as to form a mass of granulation tissue almost devoid of osseous elements. Such accumulations, however, are necessarily of limited area, since the blood supply usually fails and the mass undergoes a change, the nature of which depends upon the character of the disease of which such rarefactive osteitis is a manifestation. Some of the terminal results of rarefactive osteitis are indicated below.

Rarefactive Osteitis in Tuberculous Disease.—In the case of tuberculous disease the granulations undergo fatty degeneration and break down, so as to form what is known as "cold abscess." This will be described in the article on "Tuberculous Disease in Bone."

Rarefactive Osteitis in Syphilis.—A change somewhat similar to this takes place in syphilis, resulting in the formation of a gumma or gummatous abscess. This also will be considered in the article on "Syphilitic Disease of Bone."

Rarefactive Osteitis in Acute Inflammation of Bone.—Should an infection by

pyogenic germs, such as staphylococci or streptococci, take place, there may develop an acute process that will lead speedily to perforation of the periosteum and rupture externally, or to conditions that call imperatively for surgical interference.

Rarefactive Osteitis in Fractures and Injuries to Bone.—The process of rarefaction in these cases is altogether a beneficent one, since it is manifestly impossible for the repair of fracture of bone to take place without the conversion of the rough, abrupt ends of the bones into a softened, plastic mass capable of undergoing physiological fusion and welding. This process takes place with great rapidity, and must be regarded as physiological rather than pathological in character. It is succeeded by a condensing osteitis which results in the restoration of the solid continuity of the matrix at the seat of fracture. This will be treated further on in this article under the head of "Condensing Osteitis."

Rarefactive Osteitis in Separation of Necrosed Bone.—When a considerable portion of bone perishes—massive necrosis—as the result of such a disease as acute osteomyelitis, the dead bone becomes separated from the living by the process now under consideration. It is worthy of note that this change is a vital one, and accordingly takes place at the expense of the living rather than of the dead tissue. A thin layer of the living bone, at the line of demarcation, undergoes profound rarefactive absorption and in time the necrosed bone or sequestrum is thus entirely sloughed off from the living and lies in a cavity entirely separated from all vital connection with the living tissue. This process of rejection will be further considered when dealing with the question of necrosis in acute osteomyelitis. It must be borne in mind that, while such changes are occurring in the deeper portion of bone, the periosteum is by no means idle. It is generally engaged in the process of osteoplastic construction of new bone, so as to compensate as far as possible in strength for the weakening which is taking place as the result of the rarefying process within. Hence spontaneous or pathological fracture of bone from osteoporosis in this connection is rare.

Etiology of Rarefying Osteitis.—The causation of the condition under consideration has been largely indicated in the above paragraphs. Local injuries, as from blows, crushes, fracture, gunshot wounds, and amputations, are among the physical causes. Among causes of constitutional origin may be mentioned tuberculous disease, syphilis, typhoid fever, and the exanthemata.

The process also occurs as a reparative act in the separation of necrosed areas of bone. The absorption of bone as the result of pressure from an aneurism or tumor does not always take place by the process of rarefying osteitis, and, when a malignant growth invades the substance of the bone, it does so by the removal of the osseous structure by rarefaction and absorption. When the osteoporosis is widely diffused over the shaft of the bone and is of a mildly inflammatory type, the bone may become increasingly porous without undergoing

complete destruction. This condition seems to occur in certain cases of paralysis and in some forms of insanity, and is usually referred to as atrophy of bone. Bone undergoing the process of osteoporosis is much more pervious to the *x*-rays than normal compact bone. (Fig. 136, *c*; Fig. 138, *a*.)

Treatment.—The treatment of this condition is that of the disease or condition with which it is associated, and hence will be considered elsewhere.

Osteosclerosis, or Condensing Osteitis.

This process, which is also known as "sclerosing osteitis" or "osteoplastic osteitis" (Fig. 130), is the direct antithesis, from a pathological point of view, of the condition previously described, viz., osteoporosis, or rarefactive osteitis. It may occur in either compact or cancellous tissue of bone, or immediately beneath the periosteum, and consists in an interstitial deposit of new-formed bone, of a peculiarly dense character, in every available space. At the same time there appears to occur an increase in the proportion of bone salts in the pre-existing bone. The Haversian canals, which are narrow and slender in normal bone, become still more constricted by a further deposit of bone salts in the connective tissue immediately around the vessels. This may, indeed, proceed to such an extent as entirely to choke off the blood supply to the part, and in an extreme case may result in necrosis of the whole affected area. Usually, however, only a limited number of the Haversian canals are thus occluded, so that those remaining are able to maintain the vitality of the bone. The process is clearly one of extreme chronicity, and the density of bone undergoing this change may approach that of ivory, so that the term "eburnation" is sometimes applied to bone of this quality. Generally there occurs also a deposit of similar character beneath the periosteum, so that the whole bone becomes thickened, and gradually increases in total weight as well as in specific gravity. When the sclerosing change occurs in cancellous tissue the trabeculæ become thickened and densified at the expense of the soft medullary tissue, and thus the cancellous tissue soon resembles compact bone of an unusually dense type. Such sclerosed bone becomes entirely impervious to *x*-rays even when the exposure is of considerable duration (Fig. 130).

Etiology.—The exact causes which lead up to this condition are various, and frequently ill-defined. The two opposite conditions of osteoporosis and osteosclerosis often proceed synchronously at very short distances from each other in the same bone. For example, in a condition of chronic disease, such as may occur in very latent cases of tuberculosis, while the interior of the affected area is softening and undergoing fatty degeneration with complete disappearance of the bony trabeculæ, the margin may present a zone of bone undergoing the process of osteosclerosis. In such cases, when surgical operation is resorted to, it is frequently with great difficulty that one is able to chisel

through the dense bone in order to reach the disease which was the primary cause of the alterations found in the surrounding bone tissue.

Osteosclerosis around Foreign Bodies.—Any aseptic foreign body lodged in a bone appears to furnish, under certain conditions, just the degree of inflammatory irritation which results in deposit and secretion of this dense sclerotic bone. The writer has in his possession a bullet which entered the inner side

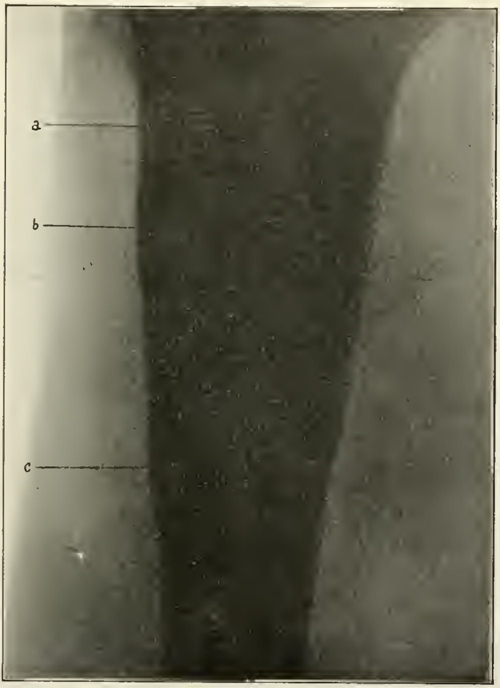


FIG. 130.—Osteosclerosis or Condensing Osteitis of the Upper End of the Tibia. *a*, The bone is quite impervious to *x*-rays; *b* and *c*, irregularities due to osteoplastic periostitis. (Skiagram by Dr. S. Cummings, of Toronto.)

of the lower end of the femur, passed through the cancellous tissue, and lodged just under the compact tissue at the outer side of the bone. A chronic sinus, discharging a minute amount of sero-pus, had existed for some three years, and, on operation, it was found that the walls of this sinus were of excessive density, and the bullet itself was firmly embedded in a jacket of bone approaching ivory in hardness, so that the chisels used in cutting through this bone were chipped and broken during the operation. Bone of a similar character has

been found by the writer surrounding small, central sequestra the result of an osteomyelitis with necrosis of a small area of compact bone deeply situated, and giving rise to a mild inflammation of very long standing.

Osteosclerosis in Rheumatoid Arthritis.—In this disease, which is known to commence by the destruction of the articular fibro-cartilage, the friction of the exposed ends of the bones against each other appears to furnish the requisite degree of irritation for the formation of new osseous tissue, which fills up the cancellous spaces adjacent to the articulation. This new-formed bone contains a great excess of lime salts, so that the process appears to be one of calcification rather than of ossification. Bone of this grade of density is capable of a high degree of polish, and the constant friction of the joint surfaces against each other produces a smooth, ivory-like appearance known as *eburnation.* As the exposed surfaces are thus progressively worn away, the condensing osteitis proceeds concurrently in the bone immediately beneath, so that a great alteration in the contour of the joint surfaces of the bone may take place. At the same time, irregular osteophytes are frequently formed around the circumferential margin of the articular ends of bones so as to give rise to a roughened, irregular appearance which has been compared to the gutterings of a wax candle. These osteophytes may or may not be of the condensed variety of new formations.

Osteosclerosis in Fractures and Other Injuries.—After the rarefactive process by which the ends of the bone are softened in the preliminary stages of repair of fractures and injuries of bone has existed for a certain length of time, there occurs a complementary change by which this rarefied and softened bone is condensed and converted into bone of normal strength and density. This process is accompanied by a shrinkage in bulk, and is clinically known as "the absorption of the provisional callus." In these cases, however, the change is a physiological and beneficent one and does not pass to the stage of production of bone of too dense a consistence.

Expansion of Bone.

This term is used by Erichsen to describe a clinical event in which the two processes of osteoplastic osteitis and rarefactive osteitis go on side by side. The compact tissue in these cases becomes altered in construction, and for the most part is more spongy than normal. At the same time there occurs upon the surface of the bone a formation of new layers due to the activity of the osteoblasts of the deeper periosteal layers. These new-formed layers, however, are extremely irregular in outline, and show evidences of the presence of Howship's lacunæ filled with multinucleated cells, or osteoclasts, with *destruction* of bone proceeding in some parts, while exuberant *construction* occurs in others. Thus, by a process of deposit of new bone by the periosteum upon the surface and

the coincident absorption of the deeper layers of the compact tissue by the process of rarefactive osteitis, the total circumference of the bone is increased and the medullary canal becomes also correspondingly large in area. In other words, the whole bone is expanded. The general contour of the bone, however, is fairly well maintained and its strength is also adequate for the purposes of support for which it is intended. (Fig. 142.)

Expansion of bone by the central growth of a tumor, such as a sarcoma, is accompanied by similar changes, except that here the deposit of bone beneath the periosteum is of more regular type and smoother. Generally speaking, however, the rarefactive process caused by the pressure of the tumor proceeds at a more rapid rate than its compensatory osteoplastic process, and the result is that sooner or later a pathological fracture at the seat of growth takes place.

OSTEOMYELITIS.

This term refers especially to inflammation of the medulla of bone, either in the hollow canal or in the cancellous tissue in the expanded extremities of the long bones. When the disease commences in one of these situations it almost invariably spreads by a direct continuity of tissue to the other. The name is applied to those inflammatory diseases of the bone in which the inflammation of the medulla forms the most prominent feature of the disease; but, as in other inflammatory conditions of bone, the remaining components of the structure, viz., the compact bony matrix and the periosteum, likewise participate in the morbid processes. The process of osteomyelitis may be appropriately considered under three principal headings, viz.: Acute Simple or Non-suppurative Osteomyelitis; Acute Infective or Suppurating Osteomyelitis, commonly known as Acute Necrosis; and Chronic Osteomyelitis.

Acute, Simple, or Non-suppurative Osteomyelitis.

Inflammation of the medulla not culminating in suppuration is usually traumatic in origin, and is unaccompanied by a growth of any pyogenic germs in the area of inflammation. The familiar form of this condition is that which occurs in fractures and sometimes in contusions of the expanded ends of long bones. Under these circumstances the condition can scarcely be called one of disease, since the processes are physiological rather than pathological in their nature, and the intent and results are benign and conservative. The process of union, as it occurs in fractures, has been fully dealt with in Volume I., page 279 *et seq.* It will be sufficient to say in this place that the process is characterized by a very early congestion of the tissues in the neighborhood of the fracture, accompanied by effusion and exudation of blood plasma,

and also accompanied by a striking activity in the reproduction and growth of the normal cells of all participating tissues. Thus, there is produced that portion of the callus which occupies the medullary canal and is sometimes known as "pin callus." This portion of the callus is, of course, directly continuous with the "interstitial" and "ensheathing callus," and ultimately undergoes organization into bone tissue, thus bringing about repair of the fracture. After union is complete the medullary canal is restored in continuity by the absorption of the "pin callus." The sequence of events following contusion of the cancellous tissue in the expanded extremities of the long bones does not differ materially from that described above, and the results of the mild inflammatory process are similarly beneficent in character.

The occurrence of suppuration in the course of the history of simple fractures is so unusual as to constitute a rare phenomenon. That such suppuration is so uncommon is the more surprising because it is found to be not difficult to induce suppuration experimentally in fractured bones of the lower animals by the injection, into the blood system, of pyogenic organisms such as the streptococci and staphylococci. When, therefore, suppuration does occur at the site of a simple fracture, it may be taken as quite certain that a lodgment of pathogenic germs has occurred at the seat of the lesion. The lowering of the vitality of the tissues, the lessening of the natural resistance due to the injury, and the effusion of blood and inflammatory products furnish the necessary depression of the resisting power which enables the germs to thrive and multiply. When this unfortunate event once becomes initiated the condition does not materially differ from that to be described under the heading of Acute Infective Osteomyelitis, which is to be immediately considered.

Acute Infective Osteomyelitis, or Acute Necrosis.

This condition constitutes by far the most important and most common acute inflammatory disease of bone. Its immediate consequences, both locally and constitutionally, are frequently so serious, and its remote results so disastrous, that a lengthy and minute consideration of the disease is imperative. It is so important that there should be no error as to the identity and recognition of the disease under consideration that it seems wise to refer to the various terms used to designate the condition by different authors. The most common, and perhaps the most appropriate names are those given at the heading of this paragraph, namely, acute infective osteomyelitis, or acute necrosis. Other terms used are: Spontaneous Osteomyelitis, Necrosial Fever, Bone Typhus, Acute Suppurative Osteomyelitis, Phlegmonous Periostitis, Acute Suppurative Epiphysitis, and Bone Furunculosis.

In order that what is to be set forth in the following paragraphs may be followed in an intelligent and logical manner by the reader, acute osteomyelitis

or acute necrosis may be briefly and comprehensively defined as follows: It is an acute, inflammatory disease of pyogenic origin occurring principally in the long bones of young people in whom the union of the diaphyses and epiphyses has not yet taken place. It occurs usually in those who have been depressed by antecedent disease or who have been exposed to inclement weather or to injury, and is marked, as a rule, by profound symptoms, both locally and constitutionally. It is liable to be complicated by acute ulcerative endocarditis, or by suppurative inflammation of the serous cavities (such as the pericardium and pleura), and almost always results in massive necrosis or death of a greater or less area of the affected bones.

Etiology.—Though acute osteomyelitis is undoubtedly a germ disease, there are certain conditions of environment, antecedent disease, and local traumatism which have such an obvious bearing in determining the onset of the

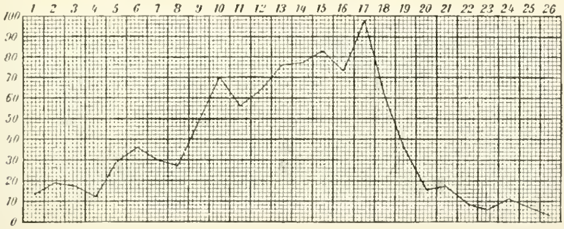


FIG. 131.—Chart Showing the Number of Cases of Acute Osteomyelitis Occurring in Different Years of Life. The numbers on the left represent the total percentage of cases affected with the disease, while those at the top of the chart represent the different ages from one to twenty-six years. As will be observed, there is a gradual rise, with fluctuations, till the seventeenth year, then a rapid fall occurs; the disease practically disappearing about the twenty-first year, when ossification is complete. (From Trendel, in *Beiträge zur klin. Chirurgie*, 1904, vol. xli., p. 607.)

malady that they may be very well considered under the heading of etiology. The disease, in practice, is found to be confined to a large extent to children below the age of puberty. It may occur, however, at any period of life before the ossification of the epiphyses with the diaphyses of the long bones is completed, but it is almost never known to occur in a typical form after that event has taken place.

A most graphic chart illustrating the relation of age to the occurrence of this disease is that given by Trendel (Fig. 131). This chart shows most conclusively that the frequency increases with the advance in years from the first to the seventeenth year in almost a directly continuous ascending curve. After the seventeenth year the drop is very rapid up to the twenty-first year, when the curve practically descends to zero, showing that extremely few cases occur after the twentieth or twenty-first year of life. This statistical chart fully agrees with what is known of the developmental changes which occur in the

growth of bones and which are known to have a debilitating effect upon the resisting powers of the rapidly growing epiphyseal region of the long bones.

Sex has also some bearing upon the frequency of the disease, as it is found that, all cases considered, males are affected about three times as often as females. This discrepancy between the sexes is much less apparent in young children than in adolescents and may probably be fully accounted for by the fact that the males are more exposed to such injuries as sprains, contusions, and wrenches which stand as exciting causes for the onset of the disease, and that they are also more exposed to vicissitudes of weather and temperature than females.

In regard to the occurrence of the disease in adults over the age of twenty-one, it may be said that such instances of osteomyelitis are in the majority of cases recrudescences of a condition which was probably present in very early life, and from which recovery was incomplete. It is quite certain that one does occasionally encounter a case of osteomyelitis in the adult, but a careful examination of the history will usually show that the condition was present in a mild form in early life.

The Effects of Constitutional Peculiarities.—The subjects of the disease are usually of a more or less feeble constitution, although there are exceptions to this rule which shall be mentioned later. Not infrequently they are of a strumous diathesis and very often are children who have been depressed by antecedent febrile diseases such as measles, scarlet fever, whooping cough, bronchitis, and typhoid fever.

On the other hand, the disease may very unexpectedly strike down those who are apparently of a robust and vigorous constitution and unusually strong and well grown. In such cases it may well be surmised that growth and development have been too rapid, and that time has not been afforded for the rapidly forming bone at the epiphyseal lines to attain such a degree of maturity as to acquire strong resisting powers to the growth and development of germs.

Peculiarities of Circulation in Growing Bones, as Affecting the Onset of Acute Osteomyelitis.—The researches of Lexer into the distribution of the arterioles in the bones of growing children and young adults, have thrown a strong light upon the part played by the blood-vessels in diseases of an inflammatory character affecting bone. His investigations, fortified by beautiful preparations and *x*-ray photographs (Fig. 132), have afforded a much-needed explanation of the frequency with which pyogenic and tuberculous foci become located near the epiphyseal lines in children and young adults, and, conversely, of the relative immunity from such infections of the same situations in those who have fully attained a normal growth.

Lexer's method of investigation is briefly as follows: Into one of the large arteries of a recently removed limb he injects an emulsion of mercury and spirits

of turpentine in such a manner that all the arterioles of the bone become distended with this metallic emulsion. Thus these vessels, down to their minute ramifications, become impervious to Roentgen rays. The muscles, periosteum, and other soft parts are now removed from the bone by careful dissection, and a skiagraph of the denuded bone yields a very graphic illustration of the manner in which its matrix is supplied through its various parts by arterial blood. Investigating, first, the phenomena of the circulation in the long bones of infants and young children, he found that the arteries supplying them could be classified into three groups, which he named, respectively, the diaphyseal, the epiphyseal, and the metaphyseal (Fig. 132, *a*, *b*, *c*). The group ascribed to the diaphysis (Fig. 132, *c*) appears to be derived almost entirely from the nutrient artery, branches of which go to each end of the bone and terminate near the epiphyseal line without any very pronounced degree of anastomosis with either the metaphyseal or epiphyseal group. The arteries which are responsible for the nutrition of the epiphysis (Fig. 132, *a*), on the contrary, are derived from various main trunks, and are distributed at various points through the medium of the periosteum clothing its outer surface. These vessels, like those of the preceding group, are also terminal in character, and seem to be confined to the neighborhood of the epiphysis on the distal side of the epiphyseal line without having any free communication with the other vessels.

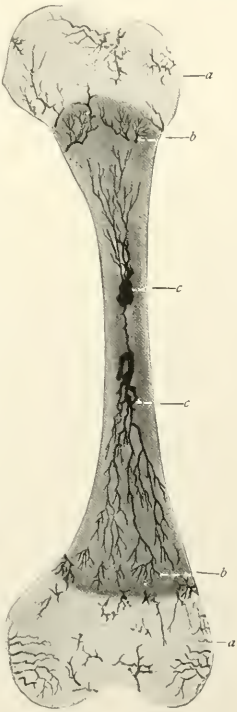


Fig. 132.—Femur of a Child Four Weeks Old. (From Lexer, in *Archiv f. klin. Chir.*, 1903, Bd. lxxi., p. 9, and Bd. lxxiii., p. 481.) *a*, *a*, Epiphyseal arteries; *b*, *b*, metaphyseal arteries; *c*, *c*, diaphyseal or main nutrient arteries. It will be observed that there is no free anastomotic communication between these various groups.

The vessels comprising the metaphyseal group (Fig. 132, *b*) are smaller and shorter than the others and enter the end of the shaft near the end of the diaphysis, with the same characteristics as terminal vessels as characterize the other groups.

From these pictures Lexer demonstrates that the areas in which osteomyelitis most often begins are supplied by terminal branches from all three of these arterial groups, but concludes that these areas, owing to the limited degree of anastomotic communication between the groups, are peculiarly susceptible to the lodgment of bacteria-laden emboli. He endeavors to explain the frequency of tuberculous disease in the same localities upon the same basis of

blood supply by terminal circulation. The argument is an excellent one and appears to be well founded on an anatomical basis, but the attempt to explain both tuberculous and osteomyelitic foci upon the same hypothesis is not altogether fortunate because tuberculous foci are almost invariably in the epiphysis, and osteomyelitic foci are almost equally constant on the diaphyseal side of the epiphyseal cartilage.

Continuing his investigations into the circulation of older children and adults, Lexer found that all three groups tend to become smaller and smaller with advancing age, but he shows that all may be distinctly demonstrated throughout the period of growth of bone—that is, until ossification is complete. After that period the vascular supply to the bones appears to diminish, while that to the neighboring joints becomes relatively more abundant.

Lexer's experiments thus furnish an explanation of the liability of the ends of bone to the lodgment of emboli, but a further important pathological factor in the rapid development of the germs contained in these emboli is explained below under the heading of The Effects of Local Injury.

The Effects of Local Injury.—It is a striking and unaccountable fact that osteomyelitis seldom follows *severe* injuries such as simple fractures and dislocations, even in those who have not yet reached the age of puberty, and yet, notwithstanding this statement, it is extremely common to find that the development of the affection has been preceded by some *slight* local injury—such as a sprain, twist, or a moderately severe blow—in the neighborhood of the affected epiphysis. Kocher believes that the slight extravasation of blood at the epiphyseal line, due to such slight injury, favors the development of any germs which may accidentally be lodged there from the blood current, and affords a convenient culture medium for their growth. Occasionally, also, the development of the disease may be preceded by climatic exposure and sudden or prolonged chilling of the body. The writer has in mind the case of a strong, active, well-grown lad of fourteen who "went in swimming" in a river from which the ice had just escaped. He was thoroughly chilled by the bath and an acute osteomyelitis of the lower end of the femur followed. The prolonged chilling of the surface areas of the body undoubtedly drives the blood to the deeper parts, and since during the period of growth the blood-vessels of the medulla of bones near the epiphyses are extremely large and low in tone, these parts naturally will suffer from great temporary congestion. Moreover, although there is great physiological activity at the epiphyses during the period of growth, the newly-formed tissues are of a very embryonic type and consequently have much less of the resisting powers by which the more mature tissues are characterized. In other words, high physiological activity associated with immaturity spells diminished resistance and greater susceptibility to disease and injury.

Relative Frequency of Osteomyelitis in Various Bones.—The long bones of the lower extremity, viz., the femur and the tibia, are by far the most fre-

quent seats of osteomyelitis. Out of a total of some one thousand two hundred and fifty tabulated cases nearly nine hundred were instances in which the femur or tibia was involved. Next in frequency to these bones comes the humerus, after that the radius, then the fibula, pelvis, ulna, and lower jaw. The occurrence of the disease in the clavicle, scapula, vertebræ, and other short bones is comparatively rare.

Multiple Foci.—The occurrence of multiple foci of osteomyelitis does not seem to have attracted as much attention from authors as the experience of the writer would have led him to expect. In the Victoria Hospital for Sick Children, in Toronto, it is by no means an infrequent experience to find more than one bone affected; such multiple foci having already developed before the child was admitted to the hospital or the development of new foci having taken place subsequently to admission. It is accordingly a routine practice, not only to examine all the palpable epiphyses at the time of admission of a suspected case of osteomyelitis, but also to keep a strict watch by periodic examinations for the development of additional foci during the progress of the case. In 1891 the writer recorded a case presenting the following points of infection: (*a*) Both tibiæ; (*b*) both astragali; (*c*) sixth and seventh ribs; (*d*) two points on spine of right scapula; (*e*) infraspinous fossa of left scapula; (*f*) the left pubic ramus. Some of these points were probably pyæmic, as there were also present a few subcutaneous abscesses.

Bacteriology of Osteomyelitis.—As already stated, the germs found in this disease are those capable of producing suppuration; in other words, they are pyogenic organisms. That found most frequently is the Staphylococcus pyogenes aureus. Lannelongue and Achard found pure cultures of this germ in one hundred and three out of one hundred and thirty cases. The Staphylococcus albus or citreus may also be a causative agent, but the mode of action of these germs does not materially differ from that of the golden form of the germ. The Streptococcus pyogenes aureus or albus is found in a fair number of cases. When it is present the disease is usually of a peculiarly virulent type, and is liable to be complicated by infection of the joints, of the serous cavities, or of the endocardium. Sometimes a mixed infection of staphylococci and streptococci is found. Still more rarely, bacteriological examination reveals the presence of Fraenkel's pneumococcus, the bacillus of typhoid, or the colon bacillus.

Otto Wyss reports, as the cause of an osteomyelitis, an anaërobic bacillus which he regarded as hitherto undescribed and which he termed *Bacterium halosepticum*.

Lipmann and Foisy isolated the Bacillus racemosus, the Bacillus serpens, and an anaërobic streptococcus from fetid, gas-containing pus in a case of osteomyelitis of the femur that occurred in a patient suffering from chronic pulmonary tuberculosis and a fetid purulent bronchitis. It must not be thought that all

cases of osteomyelitis are equally virulent for any given germ; on the contrary, the most widely divergent degrees of virulence may be met with. The factors determining the degree of virulence have regard, in the first place, to the character of the germ, and, in the second place, to the resisting power of the individual. There is no doubt whatever that the same germ under different circumstances may be either a vigorous grower, with intense toxic properties, or comparatively puny and innocuous. On the other hand, the tissues of the patient may be deprived of their normal powers of resistance by antecedent disease, such as measles, scarlet fever, and whooping cough. Occasionally one meets with cases in which a considerable abscess may be opened and drained, with the result that the constitutional symptoms subside almost instantly and the local suppuration seems to cease with surprising rapidity. On the contrary, other cases may be found in which the local disease is extremely limited in extent, yet the constitutional symptoms are so profound as to excite a feeling of alarm from the very beginning. As an example of this the author would refer to the case of which Fig. 133 is a photograph. In this case the sole area of bone infection was a space not much larger than a shilling on the shaft of the femur adjacent to the epiphysis of the great trochanter. The constitutional symptoms, however, were so severe from the beginning that a fatal result was almost a foregone conclusion. At the autopsy acute infective endocarditis was found, with thousands of minute pyæmic abscesses scattered through the kidneys, spleen, liver, liver, lungs, heart muscle, and brain.

The bearing of the pre-existence or coexistence of acute infectious diseases upon the occurrence of local manifestations in bone has been the subject of investigation and observation by numerous authors. In 1893 Eugene Fraenkel published the result of an extensive series of investigations which tended to prove that in acute infectious diseases pathogenic organisms with pyogenic properties are frequently present in the bone marrow, even when they cannot be demonstrated in the blood. He studied chiefly the ribs and vertebræ, and observed that sometimes the germ found was the specific organism of the infectious disease from which the patient was suffering at the moment, and sometimes some other organism. In 13 cases of diphtheria the streptococcus was found in the bone marrow in 9, and the Klebs-Loeffler bacillus only once. In 10 cases of scarlet fever streptococci were found in 9, and in 3 of these Staphylococcus pyogenes aureus was also present. In the very severe infections in which death occurred early in the disease bacteria were found in the bone marrow in most cases, and were always accompanied by visible inflammatory reaction. In the less rapidly fatal cases in which bacteria were found, signs of local inflammation were not always present. When the patient survives the acute disease it is probable that the marrow in most cases recovers completely and no symptoms of a bone lesion arise. On the other hand, there is no doubt that the micro-organisms in the infected areas may retain their vitality for long

periods—months or years,—giving rise to no symptoms until something occurs to arouse them into activity again. The latent period of the bone lesions of typhoid has already been referred to. In the chronic abscess of bone (Brodie's abscess) which appears to arise from an infected focus encapsuled during the course of an acute osteomyelitis, the latent period is even longer, averaging in one class of cases eighteen years.

Mode of Entrance of Germs to the Seat of Disease.—Since the disease commences deeply and almost never in connection with an open wound adjacent to the part, it is quite evident that the germs must be circulating in the blood at the time infection takes place. It is now sufficiently well known that germs of disease are almost constantly present in mucous membranes and in the skin of every individual, even in a state of health. Consequently, the existence of any ulcer or inflamed wound in the skin, mouth, intestine, or other mucous membrane, or in the throat, tonsil, or any other part of the respiratory tract, or the middle ear, may be the primary focus from which the germs are received into the blood and carried to the epiphysis, which thus becomes the seat of an infective disease. Almost the first definite bacteriological information of which we were possessed in regard to this disease was the result of Garre's somewhat risky experience in rubbing a pure cultivation from a case of acute osteomyelitis into his own skin, thus producing a crop of boils. The identity of the germ of acute osteomyelitis with that of the ordinary furuncle was thus established, and about the same time Ogston, Pasteur, and Klebs were busy isolating the various forms of micrococci, which they found to be present in almost every form of acute suppuration. In perhaps the majority of cases, however, no ulcer, boil, or other local focus can be demonstrated.

If the attack is not of such intensity that it eventuates in an early fatality, the virulence of the germ tends to diminish with the prolongation of life. In fact, the colonies sometimes die out spontaneously and suppuration subsides very speedily. In cases where the manifestations of the disease are multiple the later appearances are seldom so virulent as the primary. In addition to this, a degree of immunity which will be further referred to under the heading of Prognosis, is developed.

Pathological Anatomy.—In regard to the main features of the pathological anatomy of acute osteomyelitis, all authors and writers are practically agreed. In regard to the point at which the disease commences its manifestation there exists, on the contrary, a very great divergence of opinion among different authorities. The point at issue appears to be mainly as to whether the disease commences in the medulla of the bone, or in some other part. As a result of a careful examination of the terms used and the discussions of the process as a whole by different observers, one is forced to conclude that the discrepancy is largely due to a somewhat loose use of the term "medulla." It must be remembered that, properly speaking, the term "medulla" applies not only to the

tissue of the medullary cavity proper of long bones, but also to the red marrow occupying the cancellous tissues in the expanded extremities of the long bones in the neighborhood of the epiphyseal lines. Hence, if, in maintaining that the disease most commonly commences in the medulla, French and German writers have reference to the red marrow near the epiphyses, they are not so far out of agreement with British authors, who generally maintain that the disease commences in the spongy bone immediately beneath the periosteum near the epiphyseal line.

As a result of a not inconsiderable experience in this disease, extending over some twenty years in the Victoria Hospital for Sick Children, the writer is firmly of the opinion that in the vast majority of cases the disease commences in the spongiosa in immediate proximity to one or other of the epiphyses in growing bone, and that in many cases it remains confined to that area, though in the majority it spreads to the adjacent medulla. The reason for this has been already alluded to, viz., that there is, during the period of growth at those points, an exaggerated physiological activity, with the production of a large amount of tissue of an embryonic type, which tissue, though very active in the matter of production of new bone, possesses the diminished resisting power of an immaturely developed tissue.

The point at issue is one of something more than mere academic importance, because if it be believed that the disease has its primary seat mainly in the proper medullary cavity, any treatment short of a free opening of that cavity must be classed as quite inadequate. On the other hand, if it be established that the disease in its very early stages is located mainly and generally in the red marrow of the expanded bone and near the epiphyseal line (Fig. 133), then a much less considerable operation might be deemed adequate. This, of course, is a question of treatment, and will be taken up more fully when that aspect of the subject is under consideration, but one may state at this point that there seems to be more than sufficient evidence that in the vast majority of cases the disease in its earliest stages is largely—if not solely—confined to the red marrow and the periosteum in the immediate neighborhood of the shaft side of the epiphyseal cartilage. This probably is the view more readily to be accepted in those cases in which a causative relation can be established in connection with a local bruise or sprain. There remains, however, undoubtedly, a minority of cases in which the disease is primarily more deeply seated and affects not merely the red marrow near the epiphysis, but also the medullary cavity proper. These cases are usually identified by their obscurity and severity, and are those most difficult to differentiate from other profound toxæmias, such as typhoid fever.

Whatever view may be held, however, by different authorities, the statement may be made quite confidently that in every case of typical acute osteomyelitis in growing youths that portion of the shaft immediately adjacent to

the epiphysis (Fig. 133) becomes affected very early in the progress of the disease, and if any necrosis results it is quite certain to involve that portion of the diaphysis which is in immediate continuity with the epiphyseal cartilage. In other words, necrosis of the middle section of the shaft in this disease, without necrosis of the terminal portions adjacent to one or other epiphysis, is unknown. This point, also, is of much practical importance in view of the line of treatment recently advocated by Nichols, and will be referred to again under the heading of "Treatment."

As an apparent exception also to the above statement may be mentioned those extremely rare cases in which a disease possessing the same main charac-

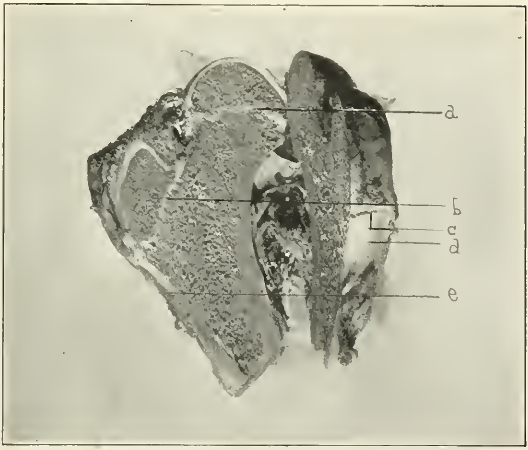


Fig. 133.—Case of Acute Osteomyelitis Commencing at the Epiphysis of the Great Trochanter of the Femur. Although this was the only focus of inflammation, the case was of the fulminating type and ended fatally on the sixth day, with multitudes of pyæmic abscesses. *a*, Epiphyseal line of head of femur (unaffected); *b*, *c*, epiphysis of great trochanter, in which the disease commenced; *d*, bone from which the periosteum has been separated by pus; *e*, lower limit of the separation. Observe that the medulla is unaffected. (Original.)

teristics affects the epiphysis alone and not the shaft. These cases will be considered under a separate caption as cases of Acute Epiphysitis.

The points mainly in dispute having now been disposed of, one may be permitted to pass to a discussion of those aspects of the pathological process upon which all are practically agreed. By reason of the resisting character of bone tissue any considerable accumulation of pus which takes place in connection with this disease must necessarily lie beneath the periosteum. When pus accumulates in the medullary canal itself or in the cancellous tissue of the red marrow, it is at the expense of the cellular elements and fat which normally occupy these areas. Either these constituents break down and constitute a

portion of the pus, or they are absorbed or forced by pressure into the open veins and lymphatics. The latter circumstance explains the fat emboli which are sometimes found in the lungs, and also the tendency of this disease to become pyæmic through the distribution of showers of germ-laden emboli. Usually within the first forty-eight hours the periosteum adjacent to the affected epiphysis becomes loosened from its connections. It is deeply congested,

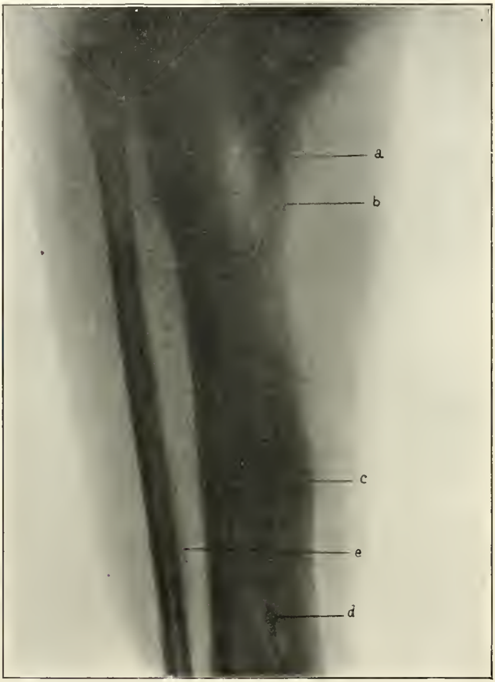


Fig. 134.—Acute Osteomyelitis of Tibia, with Scattered Sequestra, as at *d*. *a*, Osteoporosis; *b*, osteosclerosis and periostitis; *c*, a node formed under the periosteum; *e*, newly formed bone on fibula. (Skiagram by Dr. S. Cummings, of Toronto.)

thickened, and softened, and its inner layer loses its physiological contact with the surface of the bone. As the disease progresses, the accumulation of the pus tends by pressure to raise the loosened periosteum and strip it off over wider and wider areas of the affected bone. In children and young adults this membrane, though maintaining a very active physiological connection with the shaft of the bone, is mechanically much more easily separated over all parts than in individuals of more advanced years. It appears, however, to have an

extremely intimate connection with the epiphyseal cartilages. In fact, one may readily notice in operations on young people that the periosteum appears to be practically continuous with this cartilage, so that it can scarcely be separated without actual tearing of its structure. This fact has an extremely important relation to the distribution of the pus under the periosteum during the course of the disease, and is undoubtedly an important feature in the immunity of the joints from implication, which is the rule in acute osteomyelitis. Accordingly, as the pus accumulates beneath the periosteum it tends to burrow along the shaft both longitudinally and circumferentially. In cases in which treatment is neglected or in which the periosteum persists and does not rupture, the pus may thus burrow throughout the whole length of the bone as well as throughout its whole circumference from end to end (Fig. 135). Even in the most pronounced cases, however, there are certain points—such, for example, as the linea aspera of the femur and other rough muscle-bearing ridges and lines—to which the periosteum clings when it is entirely loosened elsewhere. As the disease progresses, the veins and arteries which pass from the periosteum to the bone become first thrombosed and afterward entirely absorbed or disintegrated. If at the same time the proper nutrient arteries and veins become thrombosed, necrosis of the shaft is inevitable.

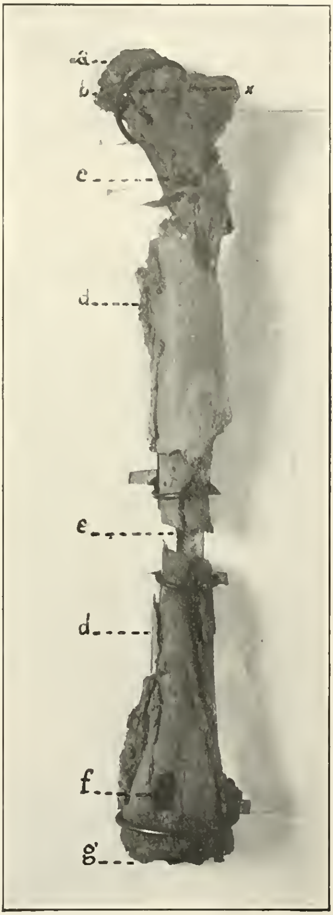


FIG. 135.—Shaft of Femur from a Fatal Case of Acute Osteomyelitis. The epiphyses of the head of the bone (a), the great trochanter (b), and the condyles (g) are all separated; yet considerable portions of the shaft survived, and with these are incorporated numerous layers of bone formed on their surface by the periosteum (d, d). At the point c the bone was fractured during removal, and at f it was trephined for drainage. (Original.)

Proceeding at the same time with this separation of the periosteum is a process of solution and disintegration by which the diaphysis becomes separated from its companion epiphyseal cartilages (Figs. 135 and 136). This naturally occurs

much more readily in very young subjects in which ossification is far from complete and in which the line of growth is particularly embryonic in character. The result of a case proceeding to this deplorable extreme is that the whole shaft of the bone from end to end and across its terminal connections with the epiphysis may lie perfectly separate and detached within the pus cavity (Fig. 135), the walls of which are formed by the detached periosteum and the epiphyses. Under such circumstances, of course, the medulla, both red and yellow, becomes necrosed and undergoes purulent degeneration. The osseous cortex and cancellous trabeculæ are obviously perfectly inert bodies during this process,

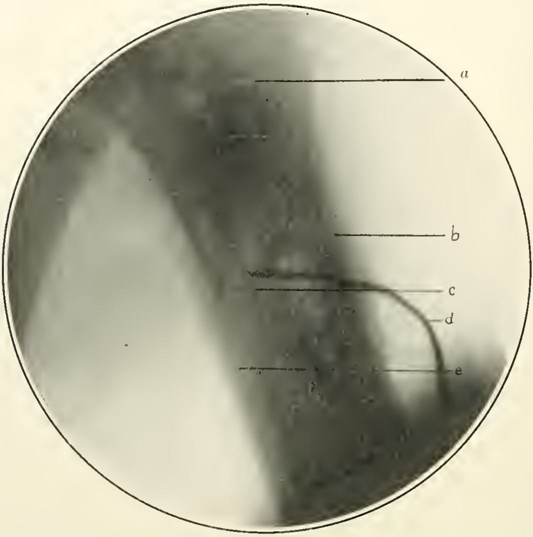


FIG. 136.—Acute Osteomyelitis of Upper End of Humerus, with Necrosis. The sequestrum is indicated by the black shadow between *a* and *c*; *b*, involucrum in process of formation by periosteum; *c*, zone of osteoporosis by which the sequestrum is extruded; *d*, a probe passed into a sinus; *e*, involucrum. (Skiagraph by Dr. S. Cummings, Toronto.)

but the bone cells within their substance are gradually deprived of nourishment and undergo coagulation necrosis and death. The picture above limned is clearly that of an extreme case that has not been subjected to treatment, and —certainly in these days of careful clinical study and observation—is, fortunately, very rarely seen. Even without treatment, such a result is rare, because usually the periosteum gives way at one or more points and permits of the escape of the pus into the surrounding soft parts. When this occurs, or when an incision provides the same means of escape, usually the dissecting process by which the periosteum is raised from the bone ceases at once, and in fact

the periosteum may fall back and recover to some extent its vascular connections with the cortex, so that not by any means all the cortex that was originally bare of periosteum necessarily perishes (Fig. 135). When the pus escapes through the periosteum it may burrow very deeply in the intermuscular and subcutaneous spaces and form large abscesses before it is spontaneously evacuated by necrosis of the skin. This is particularly true in the case of osteomyelitis of the lower end of the femur, where the pus usually escapes into the ham through the thin periosteum of the posterior surface of the lower end of the femur, the tendency then being for the discharge to accumulate in the loose intermuscular spaces of the thigh.

In those forms of the disease in which the septic process extends not only through the red marrow of the ends of the diaphysis, but also through the medullary cavity proper, the picture presented is one of a widely but irregularly diffused septic process. Nichols describes the appearance of the marrow as presenting a mottled patchwork of yellowish or greenish areas of suppuration with reddened areas of injection or hemorrhage and grayish gelatinous patches apparently undergoing coagulation necrosis. It is of course well known that there is a very free communication between the cellular spaces occupying the expanded ends of the diaphysis and the proper medullary cavity. Hence a spread by direct continuity of tissue is easily possible. The fatty portion of the soft marrow either undergoes absorption or becomes necrotic and is merged in the purulent infiltration. Sometimes the pressure of the inflammatory products within the medulla is such as to force the fatty marrow into the circulation and thus give rise to the fatty emboli already alluded to.

As Nichols also points out, the extension of the disease is always more or less irregular because of the irregular communication between adjacent alveolar spaces. When the disease advances to such a stage as to choke off the circulation through the nutrient arteries, it is obvious that the whole of the bony area supplied by these vessels must perish. Then the gray and red patches merge with the yellow to form one continuous pus-saturated cavity. Evacuation of such cavities by treatment becomes necessary, as a matter of course, since the minute channels of communication with the exterior of the shaft formed by the Haversian canals are quite inadequate to the purposes of drainage.

The condition at a later stage will depend upon the rapidity and extent of the destruction. This may be complete and the whole interior of the bone may be filled with broken-down necrotic material. If drainage has been secured and the destruction is not so extensive and the poison not too virulent, a more or less successful attempt is made to limit the spread of the infection by the erection of defensive barriers of granulation tissue which ultimately enclose the necrotic areas except where these communicate with the surface by sinuses. Bands and sheets of scar tissue are formed, at some points entirely occluding

the medullary canal. Some of the smaller infected areas may be completely encapsuled, the micro-organisms lying dormant but retaining their vitality for an indefinite period.

In the cortex or compact tissue the pathological condition is different. The dense matrix of the bone is much more resistant to the spread of the infection than are the soft tissues of the medulla, and the extensive necrosis of the cortical bone which often occurs is only in a small part due to its direct involvement in the inflammatory process. In fact, it may be said that it is due almost entirely to complete choking of the nutrient vessels which are distributed to it from the periosteum without and the endosteum within.

The Death of the Bone.—The term "acute necrosis," as applied to this disease, expresses a condition which is almost, but not quite, invariably found to follow an attack, viz., death of a massive portion of the shaft of the bone. As has been observed above, necrosis, though usual, is not an absolutely essential accompaniment of the disease. The extent to which it occurs depends of course upon the degree to which the periosteum has been separated and to which the disease has spread along the medullary cavity. The amount of necrosis, however, in the majority of cases, is determined by the separation of the periosteum rather than by the extent to which the medulla has been involved. Sometimes, as has been indicated, the whole shaft from epiphysis to epiphysis (Fig. 135) becomes detached from its periosteum and perishes, and all degrees, from that extreme condition down to the cases in which the process does not even extend to suppuration, will be found. The most usual extent is that which involves only a portion of the length of the shaft and a portion only also of its circumference. In these cases the actual continuity of the bone is not materially affected, and a failure or diminution of the growth of the bone does not necessarily occur. It frequently happens, also, that after the pus has been evacuated from beneath the periosteum, either spontaneously or by operation, that membrane falls back to its place and resumes to some extent its nutritive function toward the underlying bone (Fig. 135). Thus, it is the rule, rather than the exception, to find that the extent of necrosis is somewhat less than the extent to which the periosteum has been separated during the acute stage of the disease. Where, on the other hand, the commencing point of the disease has been in the medulla, it is possible to have a necrosis of the deeper layers without so great an extent of death of the more superficial layers of the shaft.

The form which the necrosed sequestrum takes will thus be seen to depend upon the relative degrees to which the medulla and the periosteum are affected. If the disease has been of that type in which the medullary cavity is the main seat of inflammatory change, then the internal portion of the cortex adjacent to the medulla will perish to a greater extent than that immediately beneath the periosteum. On the contrary, however, the extent to which the periosteum

is separated, as a rule, forms the index to the amount of necrosis which will probably take place.

Separation of the Sequestrum.—When the inflammatory process begins to subside, either as the result of spontaneous evacuation of the pus through the periosteum and through the skin or as the result of operative incision, the dead bone begins to separate from the living, and when the process is complete the rejected dead portion is called the *sequestrum*. The process by which the dead is separated from the living bone is one of gradual softening and absorption of a zone of bone at the line of demarcation. This process has already been described under the heading of "Rarefying Osteitis, or Osteoporosis." While it is in progress the compact tissue becomes infiltrated along its Haversian canals with granulation tissue, and the bone cells take part in the process to a slight extent. Certain individual cells, evidently derived from bone cells and commonly termed osteoclasts, are actively engaged in promoting the absorption of the compact tissue. They appear to exert a solvent action upon the bone salts, so that the bony lamellæ are gradually softened and absorbed. In this way a layer of granulation tissue forms between the dead and the living bone, the zone of cleavage being produced at the expense of the living rather than of the dead tissue. The sequestrum is usually somewhat conical in shape, the thickened end being toward the epiphysis. Its outer surface is smooth, hard, and of a dead white appearance, but its inner aspect is exceedingly irregular in outline and honeycombed frequently in a very grotesque manner.

The length of time occupied in the separation of the sequestrum from the living bone differs very materially in different cases. Roughly speaking, the larger the bone, the older the patient, and the larger the sequestrum, the longer does the process of separation require. Separation takes place more rapidly in the upper extremity than in the lower, owing probably to greater activity of circulation in the limb nearest the heart. In small bones such as the phalanges, the process may be complete in six weeks; in the femur it may require six months or more. When separation is complete, the sequestrum remains as an infected, offensive foreign body lying in a bed of granulation tissue and maintaining access with the surface by sinuses called "cloacæ" which tend to persist indefinitely, or, if they heal, soon break open again.

Regeneration of Bone.—Compact bony tissue, although possessed of considerable vitality, has very little regenerative power. The formation of new bone is almost altogether the work of the periosteum and of the membrane lining the medullary spaces. In experimentally studying the process of repair in the long bones of a cat Nichols found that the callus thrown out was almost entirely derived from these two sources, and that the dense cortical bone took but little part in the regeneration. The process of repair after osteomyelitis is carried out in the same manner. New bone is formed in two situations, in the central cavity by the membrane lining the medullary spaces, and on the surface of the shaft by the

periosteum. When first formed it is comparatively soft and bulky, but gradually becomes more dense until it is as hard or harder than the original cortex. The irritation caused by the sequestrum acts as a constant stimulant to the bone-forming membranes, probably by causing a condition of chronic hyperæmia in the affected areas, and ultimately the new bone may greatly exceed the original structure in both density and bulk. In the centre of the shaft, after removal of the sequestrum, the new formation may partially or completely occlude the medullary cavity temporarily, and on the outer surface successive layers of bone are laid down by the periosteum outside of the former limits of the shaft, greatly increasing its diameter. Buried deeply by the formation of this involucrum the sequestra lie, as before stated, in a bed of granulation tissue completely surrounded by dense bone, but communicating with the surface by sinuses—cloacæ—which afford exit to the pus through the overlying new bone.

Septic Arthritis as a Complication in Acute Osteomyelitis.—Allusion has already been made to the rarity with which joints adjacent to such an active and virulent disease are affected, but it must be remembered that occasionally the pus passes through the epiphyseal cartilage adjacent to the epiphysis and thus easily reaches the joint, with results which are usually most disastrous, not only to the integrity of the joint, but not infrequently also to the life of the patient.

Another way in which the joints may become affected is in those neglected cases in which the abscess in bursting through the periosteum spreads in the subcutaneous tissue over the adjacent joints, causing septic thrombosis, not only of the veins, but also of the arteries supplying the articulation. Thus the germs may spread by direct continuity of tissue through its thrombosed vessels into the joint cavity. Some joints are undoubtedly more liable to be infected than others, the reason being that the synovial cavity of the joint bears a much more intimate relation to the epiphyseal cartilage in some joints than in others. For example, osteomyelitis affecting the upper extremity of the femur is almost certain to terminate in suppuration of the hip joint because of the fact that the upper epiphyseal cartilage of the femur is entirely within the joint cavity. The author has had only one case of this kind under his observation. In this instance the upper epiphysis of the femur separated in the form and shape of a necrotic button of bone and was removed from the abscess cavity formed by the capsule of the hip joint.

Another joint very liable to be affected is the elbow joint in those cases in which acute osteomyelitis affects either the lower end of the humerus or the upper end of the ulna or radius. Fortunately, the disease is comparatively rare both in the upper end of the femur and in the upper ends of the radius and ulna. The lower end of the humerus is somewhat better separated from the joint, but it is not rare to find the disease extending from the lower end of the humerus to the elbow joint. One case of this nature occurred in the author's

practice, and in this case, although the disease was certainly of a very mild type with a very slight area of necrosis, drainage of the joint cavity became necessary. A fortunate result occurred in this instance, however, as the joint cavity was not disorganized and almost perfect motion ultimately resulted. Such a result is by no means unusual.

Symptoms.—As has been already indicated, the subject of this disease is generally an individual who has not yet attained his growth, and usually is below the age of puberty. Frequently a history of previous disease which has produced a certain degree of exhaustion of the system will be found to be present. The onset of the osteomyelitis is frequently announced by the occurrence of a chill, followed by high fever. The temperature, in a profound case, may reach 103° to 105° F., and this febrile disturbance is continued with remissions and exacerbations throughout the disease, or until relief is obtained either by spontaneous evacuation of the accumulated pus or by incision. The pulse rate usually bears a somewhat close relationship to the rise and fall of temperature. In the early stages the skin is hot and dry, and there is often distinct flushing, indicating the activity of the circulation and the febrile reaction.

In very young children and in very severe cases a convulsion may be an early symptom, and more or less delirium may be prevalent throughout the course of the disease.

The usual accompaniments of a high fever of a toxic type are present, viz.: loss of appetite, headache with occasional vomiting, dry coated tongue, foul breath, dry skin, etc. In the fulminating type, mental aberration, as evidenced by high delirium, may prevail throughout the entire disease; but as the vital forces become exhausted, its character changes to a muttering typhoid type, with great depression and evidence of exhaustion. In some cases such cerebral symptoms are indicative of metastatic meningitis.

It is said that when the cause of the disease is the Bacillus pyocyaneus, the discharges from the bowel are apt to be peculiarly offensive, and sometimes a fetid diarrhœa prevails.

In the fulminating type, and in those simulating the onset of typhoid with intense auto-intoxication and stupor, the local symptoms are apt to be overlooked. Even when the pain complained of is agonizing in intensity, the powers of localization of the sensation appear to be diminished. Often the child is too young to give more than a vague idea of the seat of the suffering. In older children, however, the pain is usually referred to the limb affected, but not by any means always to the immediate seat of the disease. In fact, in the early stages the shaft of the bone rather than the epiphysis seems to be the seat of greatest nerve distress. Tenderness on pressure, however, can generally be discovered quite early, if carefully looked for. In searching for the tender point, the pressure exerted should be continued for a moment or two in the neighborhood of the suspected epiphysis and on the shaft of bone adjacent.

In those cases in which the disease commences deeply in the medulla, rather than subperiosteally near the epiphyseal line, percussion of the shaft of the affected bone will elicit evidences of pain.

In a clinical case presenting evidences such as are described above, in which the diagnosis is obscure, a systematic examination of all the epiphyses should be made, since it is of the utmost importance to arrive at a diagnosis of this disease at the earliest possible moment. Every case in childhood presenting such a picture should be looked upon as at least a *possible* case of acute osteomyelitis.

Swelling at the seat of the disease is not marked until the second, third, or fourth day, as a rule, and this sign may be delayed even longer, particularly in patients with a large amount of adipose tissue. When swelling, however, does make its appearance, it is found to have its centre, not opposite the joint, as in cases of arthritic disease, but above or below, opposite one or other of the epiphyses of the bones entering into the formation of the joint. This is an important point, as helping to eliminate joint disease and also acute articular rheumatism, the condition with which osteomyelitis is most frequently confused. In an advanced case the swelling extends along the shaft to a variable distance. Before the pus bursts from the periosteum, its outlines may be marked in a fairly distinct manner, particularly in thin children, but after this event the collection becomes much diffused and difficult to outline. As the pus approaches the surface, not only does the limb appear to be thickened, but the subcutaneous tissue becomes brawny and tumid, and redness of the skin, which has been absent until this period, now becomes evident.

In those cases in which the disease affects the epiphysis as well as the end of the diaphysis, the adjacent joint may become swollen from increased intra-articular effusion. This effusion, however, may be perfectly aseptic in character, and the joint should not be opened without means being taken to ascertain by cultures whether its contents are septic or not.

Even when the swelling is quite marked, fluctuation is not easily elicited, because of the depth of the fluid from the surface. When the pus is found beneath the periosteum, this sign may indeed be entirely absent; but when it enters the subcutaneous and intermuscular planes, fluctuation may usually be discovered.

An examination of the blood shows a marked leucocytosis, and such examination should never be neglected in cases where a doubt exists as to whether the disease is osteomyelitis or rheumatism or typhoid fever.

As the disease becomes developed, a considerable amount of muscle spasm is present, usually of a tonic or contractural type. This leads to the development of certain postures, which are assumed instinctively by the patient in order to relax to the greatest possible extent the muscles and ligaments associated with the diseased area. Any attempt to alter these postures by

movement of the limbs gives rise to greatly increased pain, an increase, indeed, often amounting to agony. Hence great care should be observed not to interfere unnecessarily at this stage with the postures instinctively assumed by the patient.

In very young children the epiphysis sometimes separates from the diaphysis (Fig. 137) quite early in the disease. This occurrence gives rise to a

FIG. 137.—Separation of Lower Epiphysis of the Femur in a Case of Acute Osteomyelitis. *a*, Upper limit of separation of the periosteum; *b*, smooth bare bone deprived of periosteum and becoming necrosed; *c*, the epiphyseal line at which spontaneous separation occurred; *d*, articular cartilage. This cartilage is healthy and shows that the joint was unaffected. (Original.)

soft crepitus between the separated parts, and of course indicates a very serious form of the disease.

Complications.—In reference to the incidents which may occur during the course of this disease as complications, Park remarks that there are few, if any, infectious processes which can be followed by death from such a variety of causes and which are so augmented by dangers, if not promptly relieved, as acute osteomyelitis. The occurrence of thrombosis of both veins and arteries

of the affected bones has been above referred to, and this occurrence explains the great tendency of the disease to assume a pyaemic form of metastasis. In fact, some examples of the fulminating type appear to be pyaemic from the first. Bacteria-laden emboli break away from the clotted veins, or are forced into the circulation by the pressure of inflammatory products, and may lodge in any part of the body. These then give rise to minute abscesses in the lungs, kidneys, heart muscle, spleen, or brain, with profound toxic symptoms and other characteristic indications of the affection of these various organs.

The serous membranes also are very likely to become affected, and purulent pleurisy or pericarditis or meningitis is not infrequently the direct cause of death.

Septic endocarditis also may occur, either as an early or as a late complication in the disease. Fat embolism in the lungs is seldom of sufficient extent to cause embarrassment, unless these emboli are of a septic type, in which case septic pneumonia, with multiple abscesses, may develop, almost always with a fatal issue.

Albuminuria is frequently present to a limited extent, even when there are no embolic abscesses.

The occurrence of infection of the adjacent joints has been referred to. Suppurative arthritis may occur from extension of the disease directly through the epiphyseal cartilage and epiphysis into the joint, or from a spread of the germs through the thrombosed veins of the articulation. Occasionally also, in a neglected case, the pus may spread through the periarticular tissues into the serous cavity of the joint.

Diagnosis.—There is probably no disease in children in which the importance of an early diagnosis is greater than in that under consideration, and yet a leading text-book not many years ago was compelled to say that the diagnosis of this disease was too often made only on the post-mortem table. Fortunately, in late years a much better knowledge of the clinical characters of acute osteomyelitis has prevailed, so that failure of diagnosis now occurs in a much smaller percentage of cases.

The disease for which acute osteomyelitis is most usually mistaken is acute articular rheumatism. With care, however, and an adequate acquaintance with the phenomena of disease, this mistake should rarely or never be made, even in the first forty-eight hours. Attention to and careful application of the points described under the head of "Symptoms of Acute Osteomyelitis" can scarcely fail to bring the clinician to an accurate conclusion.

Articular rheumatism is rarely confined to a single joint, and, moreover, when it is so confined the pain and tenderness complained of are in the joint and the immediate periarticular structures, and not opposite the epiphysis or the shaft of the bone. In rheumatism, also, the central point of the swelling is opposite the joint, and becomes manifest at an earlier period of the disease

than is the case in osteomyelitis. Rheumatic manifestations never suppurate, and the disease seldom presents the evidences of septic intoxication that are present in osteomyelitis.

The pain in rheumatism is more of a dull aching character, and is seldom so severe as in the disease under consideration. Leucocytosis is not present in rheumatism and is seldom absent in osteomyelitis, except perhaps in the very mildest types, which subside without suppuration.

The characteristic sour perspiration of rheumatism also should aid in diagnosis, since in osteomyelitis the skin is usually hot and dry.

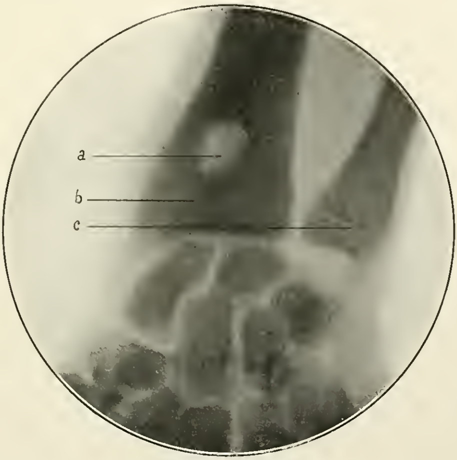


FIG. 138.—Skiagraph of a Chronic Abscess (Brodie's) in the Lower End of the Radius, just Above the Epiphyseal Line. *a*, Abscess quite pervious to *x*-rays; *b*, lower epiphyseal cartilage of radius; *c*, lower epiphyseal cartilage of ulna. (Skiagraph by Dr. S. Cummings, of Toronto.)

Typhoid fever sometimes gives rise to symptoms very similar to those of osteomyelitis, but the application of Widal's test and the absence of leucocytosis in typhoid are important aids in arriving at a diagnosis.

In the fulminating type of osteomyelitis, that comes on with convulsions and delirium in young children, the local condition may be overlooked and a diagnosis of meningeal inflammation might be made. In meningitis, however, there is usually retraction of the head with irritability of the muscles and pain on moving any of the limbs of the body.

Prognosis.—(1) As regards life. Occasionally there is encountered a fulminating type of this disease, which presents such profound symptoms and such evidences of severe auto-intoxication that a fatal result is a foregone conclusion almost from the first. Not infrequently death occurs within thirty-six hours,

and it is scarcely surprising that a diagnosis is not always arrived at in these cases, because frequently the bone lesions are quite trivial in extent (Fig. 133) and are entirely overshadowed by the constitutional manifestations. A post-mortem examination in such cases, however, will always reveal evidences of the profound toxic infection which overwhelms the whole system and interrupts the vital processes of the body. Sometimes multitudes of minute abscesses of pyæmic character may be found in the various organs and tissues of the body. Fortunately, however, these fulminating cases are comparatively rare, and in the vast majority of instances life may be saved by early and free incisions down to the bone, or, if necessary, into its medullary tissue. Nevertheless, even after such prompt treatment, occasionally death occurs during the first week or ten days, from inflammation of some of the serous membranes or from septic endocarditis or septic pneumonia. Amyloid disease of various viscera may possibly result from prolonged suppuration in cases where large areas of necrosis occur in several of the bones of the body.

Fig. 139.—Cast of the Foot of a Boy. (Pathological Museum of the University of Toronto.) The growth of the lower epiphysis of the tibia was arrested by an injury, and the foot was crowded to the tibial side by the uninterrupted growth of the fibula. *a*, Level of the internal malleolus; *b*, level of the external malleolus. The deformity was corrected by exsecting a section of the fibula.

(2) As regards the bone. Cases of osteomyelitis are sometimes so mild that the process terminates without actually producing suppuration. In such instances, of course, there is no necrosis, but there may remain a considerable thickening of the bone as a result of the accompanying osteoplastic periostitis. Such cases may be aroused into activity years later, with the formation of a chronic bone abscess (Fig. 138).

The loss of bone from necrosis varies, as has been mentioned under the heading of "Pathology," from loss of the whole shaft from epiphysis

to epiphysis (Fig. 135) to the loss of a mere shell of tissue adjacent to an epiphysis.

(3) As regards the ultimate results. When the necrosis affects the whole thickness of a shaft adjacent to the epiphyseal line, there is great danger that the vitality and bone-producing power of the epiphyseal cartilage may be impaired, with the result that, although the lost bone may be replaced by the

Fig. 140.—Cast of Hand and Forearm. The lower epiphyseal cartilage of the radius was destroyed in the patient's thirteenth year, and ceased to grow. The uninterrupted growth of the healthy ulna gradually crowded the hand to the radial side of the arm. (Pathological Museum of the University of Toronto.) *a*, Styloid process of the radius; *b*, that of the ulna.

periosteal and endosteal activity, the growth of the bone in length may be interfered with to such an extent that it will never attain the full stature of its fellow. In the case of single bones, such as the humerus and femur (Fig. 144), the only deformity resulting is a difference in the length of the two limbs, and this can usually be compensated for by artificial means. In the cases, however, of parallel bones, such as the tibia and fibula (Fig. 139) and radius and

ulna (Fig. 140), a diminished growth of one may lead to considerable deformity through the twisting of the limb to the opposite side by the continued growth of its companion bone. Such a deformity, indeed, may call for operative treatment.

Where the joints become infected, ankylosis of a bony type usually takes place, unless the arthritic condition be so severe as to call for resection of the joint or amputation of the limb.

In cases in which the after-treatment is neglected, there may also occur certain muscular contractures which result in a degree of deformity that is only to be corrected by careful treatment.

Treatment.—There is no surgical disease in childhood in which well-considered promptness and well-controlled courage in regard to treatment are more urgently required or more signally rewarded than in acute osteomyelitis. The disease is one entirely beyond the reach of ordinary medicinal remedies, whether internally administered, externally applied, or hypodermically injected, as in the case of antitoxic serums. The treatment of a disease which extends in non-fatal cases often over a period of many months must necessarily be considered under different headings.

(1) In the first place, careful consideration must be given to those measures which are to be advised in obviating a fatal issue in the early days of intense septic intoxication.

(2) Next, it is important to consider the treatment of the case throughout the tedious and trying period during which separation of the sequestrum is taking place.

(3) Afterward, the vexed question of the time at which the necrosed bone should be removed and the manner of its removal must be considered.

(1) *Treatment During the Acute Inflammatory Stage.*—As has already been indicated, applications of poultices, counter-irritants, and so-called abortifacients are absolutely useless. Not only is this true, but such makeshifts are positively pernicious, because, in addition to being utterly futile in themselves, they are time-consuming and tend to promote a false feeling of confidence and security in the minds of the patient and his friends. As has already been indicated under the heading of "Diagnosis," every disease in childhood with septic manifestations should be looked upon as a possible case of acute osteomyelitis, and the physician's or surgeon's very best endeavors should be directed to detecting the earliest revelation of this disease at one or other of the numerous epiphyseal lines in the young patient. By such systematic thoughtfulness only can the disease be detected sufficiently early, not only to save the patient's life, but also to limit in a very important degree the extent to which the bone itself will suffer. When the surgeon has decided that disease exists in the neighborhood of one or more of the epiphyses, he should lose no time whatever in making the necessary incisions down to the seat of inflammation.

He should not be content with finding evidence of disease at one epiphysis without also making himself equally certain of its absence at all others. Moreover, an unnecessary incision is less to be deplored than the neglecting of a needed one. The incisions made should be as free and as numerous as the case requires, but indiscriminate slashes of unnecessary length and in haphazard positions are much to be deprecated. The greatest care also should be taken to respect the anatomical features of the locality in making the cuts. It is quite true that some of the epiphyses may be reached with absolutely no danger to important structures, but, on the other hand, there are many places where incisions may be required in which anatomical skill and knowledge are

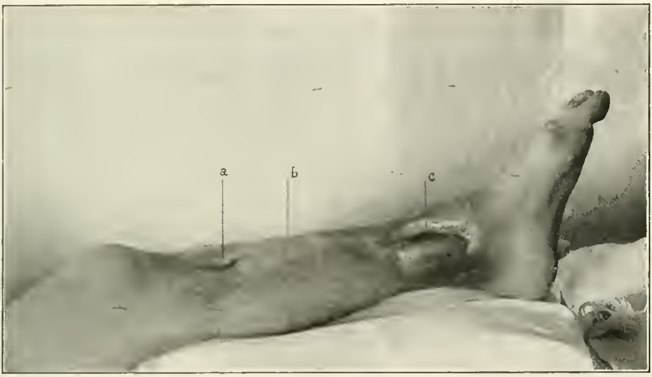


FIG. 141.—Acute Osteomyelitis Affecting Both Extremities of the Shaft of the Tibia. Sequestra were removed from the cloacæ *a* and *c*, but the main portion of the shaft survived. *b* Shows thickening of the bone due to osteoplastic periostitis. (Original.)

indispensable requisites in the individual undertaking such surgical treatment. For example, the external popliteal nerve in the leg and the ulnar nerve in the arm are each so placed as to render it necessary that they should be carefully avoided during operations for disease in these regions, and in nearly every one of the epiphyses of the long bones the careless surgeon might open a joint cavity with results likely to be extremely disastrous. When the question of operation on individual epiphyses comes to be considered, the necessary instructions as to how injury to important structures may be avoided will be pointed out more fully.

After having so strenuously advocated above the importance of early and free incisions, it may perhaps at first view appear out of place to utter a word of warning in the opposite direction. But, if one may judge from the reports published in recent journals in regard to the discussions held on this subject at the meetings of various societies and associations, it has become abundantly

evident that the enthusiasm and boldness of some surgeons require to be restrained. When one reads of incisions being recommended as routine treatment—incisions which are to extend from end to end of such a bone as the femur, or even the tibia—with a gouging out of a gutter through the compact bone from epiphysis to epiphysis and a thorough curetting of the medullary cavity, one cannot but feel that such surgeons, in aiming at a superlative degree of merit, have quite overstepped the bounds of prudence and discretion. It must be understood that, while free incisions are commendable, they are not so in direct proportion to their length. The operation cited would in itself be one of very considerable gravity on a healthy individual, and the shock and loss of blood resulting from such heroic treatment on a patient whose resisting power is already taxed to its utmost, and who in addition has for certain entered upon a very prolonged and serious illness, might easily turn the scale in the wrong direction and result in a fatal issue. It may be further pointed out that, with the exception of the tibia and ulna, there is scarcely a bone in the body which can be so treated without grave injury to important muscles and other tissues. Moreover, it is quite certain that everything in the way of drainage that could be attained by such an operation can equally well be attained by a much less serious one. Let us suppose, for example, in a case of acute osteomyelitis of the tibia, that the disease has commenced at one epiphysis, has separated the periosteum the whole length of the bone and throughout a considerable part of its circumference, and has finally reached the opposite epiphysis. In such a case it is quite certain that all that could be desired in the way of drainage can be attained by an incision, say, from two and one-half to three inches in length, at each extremity of the shaft. Such incisions would permit of the escape of all subperiosteal pus, and would also permit of through-and-through irrigations, if that were deemed advisable. (The question of treatment of the medulla in such cases will be considered later.) There would still be left, in such a case as we are here supposing, a complete ring of periosteum extending circumferentially about the bone throughout the greater portion of its length, and the presence of this ring or cylinder of periosteum is very greatly to be desired from the point of view of rejuvenation of the shaft of the bone after the sequestrum has separated and been removed. Where the pus has ruptured through the periosteum and has invaded the intermuscular spaces and subcutaneous tissues, other incisions may be required. These incisions should, as a matter of course, be made as much as possible in dependent positions, but, as a rule, an incision three inches long (Fig. 141) will be quite as efficient, from the point of view of drainage, as one seven or eight inches long. In making such incisions great care must be observed to avoid not only nerves and arteries, but all considerable veins, and if any vessel is seen to bleed freely it should be immediately caught and either ligated with catgut or twisted. Hot sponges should also be at hand, ready to be applied to the fresh cuts, in order that by pressure and by the ap-

plication of heat the loss of blood may be obviated as much as possible. In dressing these wounds after the incisions have been made down through the periosteum to the bone, care should be taken not to separate unduly the periosteum from the underlying bone by the gauze. It should be remembered that very little pressure may suffice to separate to a harmful degree the softened and inflamed membrane from its underlying bone, and also that, if the pus be freely evacuated, the periosteum may fall back and resume, to some extent at least, its nutritive functions toward the bone from which it had been separated by the dissecting force of the accumulated pus. It is certainly the rule in practice that such incisions through the periosteum are followed by very gratifying amelioration of the symptoms. The temperature usually drops almost or quite to the normal level, the pulse improves and becomes slower and steadier, and the patient takes on an appearance of well-being. The pain is usually almost entirely relieved, and such a case may pass rapidly toward constitutional recovery, although there may remain for weeks or months sinuses that lead down to bare bone (Fig. 142). The cases in which complete resolution takes place without any loss of bone substance are certainly rare, although occasionally one does meet with such a case. Usually, however, with careful treatment the septic symptoms may be kept quite in abeyance and the patient may thrive fairly well through a period of many weeks or months during which nature is exerting her efforts to throw off the necrosed area of bone. During this period great latitude must be allowed, in the matter of dressings, to the preference of the individual surgeon under whose care the case may be. Some cases seem to do best under wet dressings, but in the majority of cases it will be found that bulky and rather loosely applied dry dressings of fine gauze and absorbent cotton will be most satisfactory. By the arrangement and number of the incisions the drainage should be made so efficient that no accumulation of pus in pockets can take place. If, however, it is evident that the whole of the pus cannot be efficiently drained away, irrigation may be adopted, and here again the surgeon is free to choose the character of the solution which shall be used.

Fig. 142. Shaft of Tibia, showing Effects of Chronic Inflammation with Sinuses Leading to the Medulla. *a*, The line of the upper epiphysis; *b*, sclerosed and thickened bone; *c*, *d*, and *e*, cloacæ and sinuses leading down to the medulla. (Original.)

The benefit of irrigation in such cases is largely mechanical, so that sterilized water or normal saline solution is probably almost as good as an antiseptic solution. Certainly, no powerful antiseptic should be used; or, if it be found necessary to employ such a strong agent, a stream of sterilized water should immediately afterward be injected in order to prevent absorption through the walls of the wound. A solution of bichloride of mercury of the strength of about 1:5,000, or one of carbolic acid of 1:60, may be used. Other surgeons prefer boracic acid or argyrol or potassium permanganate. Frequently a change from one chemical to another seems to be followed by beneficial results.

The Question of Opening the Medullary Cavity.—Upon this point, again, opinions of surgeons of repute are at great variance. Some go so far as to say that in every case of acute osteomyelitis any treatment falling short of a free opening into the medullary cavity is so inadequate as to be deemed reprehensible. Such surgeons of course hold that the disease always commences in the medulla of the bone. Others, who hold that very often the disease is confined, in its early stages at least, to the red marrow and periosteum near the epiphyseal lines, consider that in the majority of cases such free incisions as have been described—incisions which reach the diseased areas—are adequate for all the purposes of drainage. Even these surgeons, however, who hold and practise the more conservative method of treatment, agree that in a certain percentage of cases the medulla is intensely affected and requires to be reached and drained by trephining (Fig. 135) or chiselling. Such cases, as a rule, are of the fulminating type or present very profound symptoms of toxæmia, with great depression of the vital forces. The nervous system seems to be almost overwhelmed, so that delirium or stupor may be present. In such cases, particularly those in which very little pus is found upon reaching the periosteum, the operation should be extended to trephining or cutting away the compact tissue so as to reach the red marrow or, if thought advisable, the yellow medulla of the bone. Nichols, while advocating not merely trephining the extremity of the bone, but raising what he calls a "lid of bone" from the entire length of the shaft in advanced cases, calls attention to the important fact that the integrity of the endosteum is essential for the vitality of the inner layer of the cortex, and urges that the whole of the medulla should not be curetted. This recognition of the great functional value of the endosteum is certainly important, and the value attaches in an equal degree to the thin prolongation of endosteum which lines the cancellous spaces in the expanded extremities of the bone. But, important as the endosteum is, the periosteum covering the bone is vastly more important, and it is difficult to see how the splitting of it from end to end of the shaft of a bone can be justified. If the shaft should perish from end to end it is by no means difficult to pass an instrument through the trephined opening at one extremity to that at the other, so as thoroughly to drain the medullary cavity throughout. This procedure

yields, in the matter of evacuation of pus, everything that can be gained by guttering the bone from end to end, and at the same time leaves intact the bulk of the periosteum in its circumference as well as in its length. It is impossible to say, during the acute stage of the disease, how much of the bone is destined to perish and how much may undergo recovery (Fig. 135), and every effort of treatment should have respect to the possible viability of portions of the shaft which may at the time be entirely stripped of periosteum.

(2) *Treatment During Separation of the Sequestrum.*—The treatment advocated above will of course be continued during the early days or weeks of the disease, as may be deemed advisable by the attendant surgeon. Drainage and cleanliness are the important points to be remembered in regard to local treatment. Every care should be observed to prevent the entrance of putrefactive or saprophytic germs. As a rule, the limb should be shaved occasionally, and the dressings should be bulky and should extend well beyond the limits of the wounds so that all the pus discharging will be absorbed and retained by the dressings. In the early stages it may be necessary to change the dressings twice a day, but, if carefully applied, a single dressing in twenty-four hours will be sufficient after the very early active suppuration has subsided. As a rule, also, the limb should be supported on a comfortable splint. This adds greatly to the ease of the patient and furnishes a very much needed support in some cases to the weakened epiphyseal attachments. If epiphyseal separation has already occurred (Fig. 137), which is by no means the rule, the application of a splint is as essential to the conduct proper of the case as it would be in the case of a fracture. During this stage, also, the greatest care must be taken of the constitutional, welfare of the sufferer; the condition of the bowels and digestive organs should receive great attention, and the patient's appetite must be catered to so as to maintain to the highest possible degree the nutritive functions of the body. Generally speaking, the patient should not be rigidly confined to bed unless there has been separation of the epiphysis, but, the splint having been applied, he may then be placed upon a couch or wheel chair and moved daily into the fresh air. If the disease be in the upper extremity he may of course be permitted to walk about, and, in mild cases, even when the disease is in the lower extremity, he may be allowed to move about with the aid of a crutch, supplemented perhaps by extension. Care must also be taken to prevent the acquirement of permanent deformities from muscular contractures, and to this end the application of the splint and judicious massage and passive movements of the joints lend their aid.

(3) *Removal of the Sequestrum.*—Bone tissue which has been deprived of its nourishment by the choking and obliteration of its blood-vessels, sooner or later loses its vitality, and thus bears the relation of a foreign body to the surrounding tissues which have escaped the destructive process. At first there is, of course, direct physical continuity between the dead and the living bone, and

the process by which the separation and rejection of the dead portion take place has already been considered. Allusion has also been made to the length of time required for the separation of the sequestra in different bones and at different periods of life. Ordinarily, a moderate-sized sequestrum in a shaft bone of a child under thirteen or fourteen years of age will be entirely separated in from six to twelve weeks. During the time that such separation is taking place the periosteum is engaged in the formation of a new shell of bone—the involucrum—which is nature's physiological attempt to furnish support to the limb in the ultimate absence of the portion of bone which has suffered necrosis. It seems the part of wisdom, accordingly, not to attempt the removal of the dead bone until a periosteal growth of considerable thickness has occurred. It must be borne in mind that, although the dead bone acts as a foreign body in the tissues, it is in itself inert and becomes merely an incident in the pathological process by which it is separated and thrown off and its place supplied by newly formed bone. Though it may interfere to some extent with drainage and afford a lodgment to pus and decomposing matter, it, in itself—by virtue of its chemical composition—is practically incapable of decomposition. Therefore, if perfect drainage be carried out, the mere presence of the sequestrum is not a circumstance which greatly interferes with the patient's health. Indeed, it may, by acting as an internal splint, add to his comfort. Accordingly, it is the usual practice, and a practice based not only upon the best traditions of surgery, but upon the best physiological grounds, patiently to await nature's efforts to separate the dead from the living tissue before making any attempt to remove by operative measures what is rejected. It has already been said that, until the line of definite demarcation has been formed by the development of a zone of osteoporosis which ultimately terminates in a separation of the sequestrum, it is impossible to state how much of the bone is destined to perish and how much, even though apparently deprived of periosteal nutrition, may undergo recovery. Even in those cases in which the whole shaft has apparently perished from epiphysis to epiphysis (Fig. 135), the writer believes that the best ultimate results will be obtained by leaving the dead shaft in its place until a definite tubular cylinder of periosteal bone has re-formed about the old decayed shaft. In this case, however, when it is definitely known that the shaft has perished, in addition to establishing perfect drainage from the periosteal abscess, the cancellous tissue should be trephined and gouged out at each end, and the whole length of the medulla should be scraped out between these two openings so that a stream of irrigating fluid may be readily passed from end to end of the necrosed shaft. If this be done, the remaining cortex lies within the limb and acts as a very perfect internal splint and also as a scaffolding upon which the new bone may be formed. It is quite true that under these circumstances the newly formed bone has a diameter much in excess of its original size, but when the old shaft is ultimately removed this gigantic bone quickly

dwindles by a process of physiological shrinking, so that in the course of time the bone practically assumes the size and shape of its original model.

Nichols, in 1898 and again in 1904, recommended a plan of operation quite different from that advocated above. His plan is to remove a definite portion of the shaft extending from the affected epiphysis to a point beyond the infected marrow. He strips the periosteum not only from the necrosed portion of the shaft, but from any other portion of the circumference of the shaft which subtends the necrosed portion. Hence, since it is very unusual for the periosteum to be stripped throughout the whole circumference as far as the marrow is infected, Nichols' plan involves the removal not only of the portion of the shaft which inevitably would die, but of a certain portion which would almost inevitably have recovered. He then stitches together the periosteum with catgut and applies a splint. The time he selects for the operation is about eight weeks after the acute infection has subsided by spontaneous or operative evacuation of the pus. At this time well-marked ossification can be demonstrated in the enveloping periosteum, yet that membrane still remains plastic. Nichols claims for this method better results than can be obtained by the plan given above, but it is impossible to justify the removal of any considerable portion of living bone, and, moreover, the results obtained by the less aggressive course of treatment are in the vast majority of cases all that can be desired. Hence the plan advocated by Nichols is not recommended. If the operation of removal of the sequestrum is undertaken at a judicious period, viz., when it is practically separated from the adjacent living bone, the regeneration of the shaft as a whole will almost without exception be completed within a few months, and the occurrence of chronic abscesses which refuse to heal is an event of the greatest rarity. It may be quite true, as Nichols claims, that if the sequestrum be allowed to remain for many months or even years, it becomes enclosed in a cavity or box of dense, ivory-like bone, and that, when it is removed from such a cavity, there is a greatly diminished tendency for this cavity to become obliterated by the development of new bone; but this certainly does not apply to cases in which the sequestrum is removed as soon as separated by nature's process.

The best way of forming a judgment as to the exact time at which a sequestrectomy should be done is perhaps by carefully estimating the length of time that would probably be required in the particular case in question to effect the separation of the dead from the living tissue. When the affected bone is comparatively superficial and the sequestrum of moderate size, one can often detect a slight movement of the dead part by the tactile sense as applied with a probe. If there are two cloacæ some little distance apart, the sequestrum may sometimes be rocked between two probes. The patient should be prepared for a sequestrectomy as if for a very considerable operation, which it may in fact turn out to be. The part should be shaved and thoroughly disinfected, and as much care should be taken to prevent the entrance of additional germs as if a

primary antiseptic operation were being performed. A certain amount of pus will, of course, usually be present, and this should be carefully mopped up by gauze or sponges very frequently during the operation, so as to prevent infection of the newly cut edges of the wound. The existing cloacæ should be utilized during the operation, if possible; and frequently by joining such openings a sufficiently large aperture may be made. The periosteum should be stripped from any portion of the involucrum which may require to be chiselled or sawn away, and in raising it great care should be taken to injure its internal surface to the smallest possible extent. In removing the involucrum with chisels, gouges, or forceps, this newly formed bone should be sacrificed over as small an area as possible and in a longitudinal rather than in a circular direction. If the sequestrum is large it will usually be quite possible to split it up by a chisel or by cutting forceps into pieces which can be removed through an aperture much smaller in size than the total size of the sequestrum. Much care should be observed in lifting out the sequestrum. It should be grasped by a pair of forceps and gently extracted by a slight rocking movement. In this way there is much less danger of breaking off minute spicules from its edges and leaving them behind to still keep up irritation.

After the bulk of the sequestrum has been removed, much discretion is required to estimate just how much of the pus-smeared granulation tissue that lines the cavity should be removed, and, following Nichols' suggestion, great respect should be shown to any tissue which has even a fighting chance for life.

Some authorities recommend swabbing the whole cavity after operation with ninety-five per-cent pure carbolic acid, followed by an application of alcohol. If the instructions above given, to carefully mop up all pus and to curette away all unhealthy granulations, be followed, such an application of a strong chemical disinfectant seems unnecessarily harsh. If such an application be made it must necessarily result in the destruction of at least some of the bone cells and osteoblasts lining the periosteum.

If the operation be an extensive one, the application of a tourniquet at a good distance above the seat of operation—and after emptying, by elevation, the venous blood as well as possible from the limb—will be found to be a great advantage. When the operation is completed under these circumstances it is well to pack the wound very firmly with gauze and to apply a bulky outer dressing with considerable pressure before removing the tourniquet. This will prevent an undue loss of blood, and, if the cavity has been well cleansed during the operation, usually it will be quite appropriate to leave that dressing in place for from forty-eight to sixty hours. It can then be removed with but little pain to the patient and generally without starting up any hemorrhage whatever.

It must be remembered that this operation may turn out to be much more difficult than a superficial examination would lead one to expect; hence, every preparation should be made for an operation of considerable magnitude.

The Question of Amputation in Acute Osteomyelitis.—There are a few cases of osteomyelitis so severe and so threatening to life, even during the acute stage, that some authors recommend amputation as the only means of averting death. Such cases are those in which the disease is very extensive in the medulla of the bone and in which thrombosis of the vessels of the bone rapidly extends to the main veins of the limb. If, in addition to these circumstances, it be found that the disease has invaded one or more of the joints adjacent to the affected bone, so as to produce a suppurative arthritis, amputation above the highest affected joint appears, without doubt, to afford the only hope of saving life. It must also be acknowledged that the chance given the patient by such a major operation, under the circumstances narrated, is an extremely slim one, and this should certainly be plainly pointed out to the patient or the patient's friends. If the operation be done in this stage and it be found that the main veins of the limb are thrombosed, a careful dissection should be made along their course to reach, if possible, the extreme limits of the thrombosis. The veins should then be ligated and the whole of the diseased portion removed. In making this dissection, also, it is important to use the utmost gentleness, as otherwise a portion of the septic thrombus may be cast suddenly into the venous circulation, with an immediately fatal result. Should the patient, however, survive the earlier acute stages of the disease, amputation may still be called for as the result of exhaustion from the pain, failure of nutrition, and prolonged suppuration, which are the accompaniments of this disease. Again, the joint or joints adjacent to the diseased bone may become secondarily affected later on in the disease, and this circumstance occasionally calls for either excision of the joint or amputation of the limb.

Acute Osteomyelitis as Affecting Individual Bones.

For the fuller guidance of those seeking information in regard to the treatment of acute osteomyelitis, it seems desirable to make special reference to the disease as it manifests itself in individual bones. This is the more necessary because, although the disease, from a pathological point of view, is fairly constant in its manifestations and in the line of treatment which it calls for in all its general outlines, there are certain anatomical considerations not to be ignored in special instances of the occurrence of the disease.

The Femur.—Next to the tibia this, as an individual bone, is probably the most frequent seat of this disease. According to the statistics of Haaga this bone is affected in thirty-nine per cent of all cases. The lower end of the femur is very much more frequently affected than the upper end, but the epiphysis of the great trochanter, by reason of its exposed position and its consequent liability to injury, is a not infrequent seat of the disease (Fig. 133). Owing to the great size of the bone, its depth from the surface, its proximity to

the torso, and the liability to infection of the hip joint when the disease is manifested in its upper end, the occurrence of acute osteomyelitis in this bone is more serious than in the smaller bones and those more superficially situated. If the disease is of a profound septic type, with involvement of the whole of the shaft (Fig. 135), a fatal issue is not by any means infrequent, particularly if it is accompanied by septic arthritis of the hip joint or of the knee joint, or if septic thrombosis of the veins of the bone extends to the main femoral vessels. In untreated cases, especially of the lower end, the natural tendency seems to be for the abscess to open on the outside between the vastus externus and the biceps, or on the inside between the vastus externus and the adductor muscles. This furnishes an indication as to the points at which incisions for drainage purposes should be made. When the incision is to be made on the outside of the lower end of the thigh, the greatest care should be taken to avoid injury to the external popliteal or peroneal nerve, which lies quite close to the tendon of the biceps. On the other hand, when the inside of the thigh is the seat of election for the incision, the internal saphena vein must be avoided, and it must also be remembered that the great vessels of the thigh, in passing from Hunter's canal to the posterior aspect of the limb, are not very far from the upper end of the incision. Whether, however, the incision is made on the inside or the outside it must be borne in mind that the synovial sac of the knee joint is in close proximity to the lower end of the femur and sometimes extends upward along the shaft of the bone to an extent of three or four inches. This sac should be carefully avoided, both by means of anatomical knowledge and by flexing the leg, as, if it be opened, a septic arthritis of very serious character may be set up.

The same general rules should be followed in an operation for the removal of a sequestrum from this situation, but if the necrosis has been so extensive as to involve the whole of the lower end of the shaft of the bone—a condition sometimes known as "total necrosis"—it may be essential to make an incision on both lateral aspects of the limb, and, since the necrosis almost invariably involves that portion of the posterior surface of the bone subtending the popliteal space, very great care should be taken to avoid the popliteal vessels and nerves.

When the disease involves the upper end of the femur the hip joint can scarcely escape infection, because the upper epiphysis is entirely included within the joint capsule. When such a condition of acute septic arthritis is diagnosed, it becomes necessary at once to make incisions to reach the accumulated pus, and so essential is it to secure thorough drainage that incisions both in front of the joint and behind are urgently called for. The anterior incision should be made in a position between the tensor vaginæ femoris externally and the sartorius and rectus internally. This should be accompanied by an incision behind

which involves a separation of the fibres of a portion of the gluteus maximus and reaches the capsule at its posterior aspect. A blunt instrument passed through the anterior wound, so as to make the capsule bulge behind, is a great aid in making the latter incision. As has been before observed, separation of the button-like upper epiphysis is quite certain to take place, and this sequestrum must subsequently be removed. When the disease is so extensive as to include the total diameter of the shaft, throughout part or the whole of its length, the greatest care should be taken to support the limb on a splint, and to apply very gentle extension, as in the case of so-called hip-joint disease, otherwise shortening of the limb and curvatures from muscle contractions are apt to take place. Moreover, after removal of the sequestrum, the patient should not

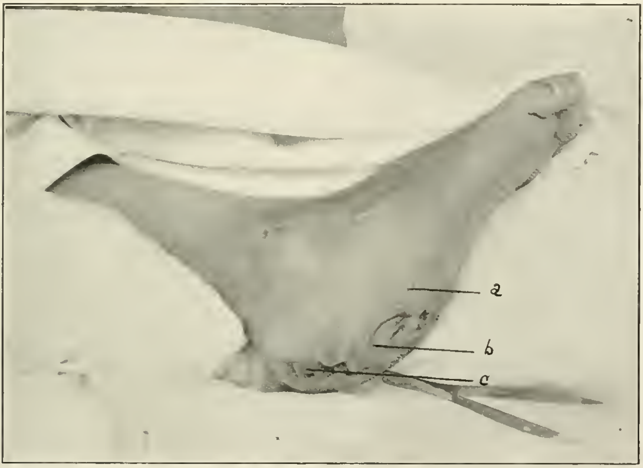


Fig. 143.—Osteomyelitis of the Os Calcis. *a*, Great inflammatory thickening of soft parts; *b*, necrosed portion of body of bone; *c*, position of epiphysis which did not die. (Original.)

be allowed to walk without supports for a considerable time, as the weight of the body also tends to produce undesirable curvatures and shortening unless ossification of the newly formed bone has been quite completed.

Radius and Ulna.—The upper epiphysis of the radius is completely embraced by the orbicular ligament, so that disease of the shaft of the radius means that the joint is almost certain to be infected if the inflammatory process reaches the upper epiphysis. Likewise, also, disease of the shaft of the ulna at its upper end is almost certain to involve the joint. Hence, acute osteomyelitis of either the radius or ulna at their upper ends is wellnigh certain to be associated with acute suppurative arthritis of the elbow joint. Hence, also, incisions made for disease of these bones must take into account that

it may be necessary deliberately to open and drain the elbow joint. Usually such treatment at best will be followed by complete bony ankylosis of the joint, but occasionally some degree of movement may be obtained after repair is effected.

The ulna is accessible to operation throughout its length along its inner and posterior border without the division of any muscular structures and without endangering any other important tissue. The radius also can be reached between the tendons of the supinator longus and the extensor carpi radiales, in the lower half of the forearm; but in approaching the lower epiphysis care must be taken not to injure the tendons of the two latter muscles as they cross the outer surface of the radius. In the upper end a dissection must be made down between these muscles, and some fibres of the supinator brevis will necessarily require to be divided. If there has been extensive infiltration of the soft tissues and burrowing of pus in the intermuscular planes, much limitation of the mobility of the fingers and hand is apt to persist, and massage and long-continued and persevering passive movements may be necessary to avoid the fixation of the fingers by muscular contractures and the binding of the tendons in their sheaths.

Marked deformity sometimes results from disease of one bone while the other retains its integrity. The epiphysis of the bone that was diseased sometimes fails to grow at the same rate as that of its companion bone; hence, if for example the growth of the lower epiphysis of the radius has been interfered with, the unrestrained growth of the ulna will gradually crowd the hand toward the radial side so as to produce a deformity somewhat similar to Colles' fracture (Fig. 140). Should this deformity become very pronounced, a portion of the shaft of the ulna may be resected so as to make the bones again of equal length.

Tibia and Fibula.—The tibia is outstanding in regard to this disease through being the bone by far the most frequently affected, whereas the fibula is affected with marked infrequency. Haaga, from von Bruns' clinic, reports that the tibia was the seat of disease in forty-two per cent of all cases, while the fibula was affected in only three per cent. The most usual seat of the disease, here as well as elsewhere, is in the spongy cancellous tissue between the epiphyseal cartilage and the proper yellow marrow of the bone. Sometimes both the upper and lower ends are involved while the middle of the bone remains unaffected, but in other cases the disease spreads throughout the medulla from end to end of the bone. The upper epiphysis of the tibia is a comparatively thin plate of cancellous bone, and if the disease is markedly virulent it may promptly spread through this epiphysis and affect the knee joint. Again, it may spread through the lower epiphysis and similarly affect the ankle joint. These complications are rare, but add enormously to the gravity of the disease, and may call for amputation of the limb. Owing to its superficial position, however, the tibia early reveals the important objective symptom of local swelling at the seat of

greatest pain and tenderness, and, if prompt treatment be adopted, very often the course of the disease may be arrested before any large amount of bone becomes affected. When the periosteum becomes distended with pus the subcutaneous veins become very distinctly marked. In severe cases, also, separation of the upper or lower epiphysis may take place, and in such cases the application of a splint is urgently required, not merely for the relief of pain, but to maintain a correct attitude of the limb while the new periosteal bone is being formed.

In regard to treatment, as has already been explained, the superficial position of the tibia facilitates early operation, and, as soon as the swelling is diagnosed, no time should be lost in making an incision through the periosteum. This will frequently be found to lead to an immediate amelioration of the symptoms of pain and fever, but, if it should not do so, it may be taken as an indication either that there are other epiphyseal foci of disease or that the medullary canal proper of the tibia is affected. This would urgently call for trephining and chiselling through the compact tissue in the line of incision so as to reach the disease in the medulla.

When the stormy symptoms of the disease have disappeared and sufficient time has elapsed for the separation of the sequestrum by a process of extrusive osteoporosis, the question of dealing with the removal of the sequestrum must be considered. As a rule, the whole of the shaft is not involved, and the portions which are necrosed may usually be removed through openings in the involucrum made by enlarging—and, if necessary, joining—the existing cloacæ (Fig. 141). Openings should be made as much as possible in the length of the bone rather than in its circumference, as this has a very important bearing upon the strength of the bone and its power to sustain weight. Even in the case of total necrosis of the whole shaft it will never be necessary to do more than make sufficiently free openings in the upper and lower extremities of the ensheathing bone. Through such openings the whole of the dead shaft may be removed by splitting it up into pieces by bone forceps or chisel, should such demolition of the sequestrum be necessary. Even if the gutter should require to be made of considerable length, a few bridges should be left across it to hold the lateral portions of the gutter firmly together, as this adds enormously to the strength of the newly formed bone.

The Humerus.—Like the femur the humerus is deeply seated from all aspects and lies embedded in muscular tissue, with very important nerves and blood-vessels on its anterior, inner, and posterior aspects. Von Bruns' statistics show that the humerus is affected in eleven per cent of all cases, and that the upper end is the seat of disease much more frequently than the lower. The upper epiphyseal cartilage is entirely extra-articular, and hence disease of the upper end of the shaft may be very extensive without any involvement of the shoulder joint. The epiphyseal surface, however, is not very large in area, and, since the muscles of the arm and thorax are strong and heavy, separation of the

upper epiphysis is not a very rare event. When this takes place a deformity very similar to that produced by traumatic separation of the epiphysis or by fracture of the surgical neck of the humerus may result. This deformity consists in the head of the humerus being rotated upward and outward by the action of the supra- and infra-spinatus muscles, while the lower fragment, viz., the upper end of the diaphysis, is drawn inward and upward by the pectoralis major and latissimus dorsi and upward by the biceps, triceps, and coracobrachialis. Such deformity must be watched for and corrected by the application of a suitable splint such as the Aikins' hoop-iron splint (*British Med. Journal*, June 5th, 1897).

When pus accumulates and is not artificially evacuated, it tends to perforate the structures on the anterior surface of the limb along the anterior border of the deltoid muscle. This furnishes an indication as to where the incision for drainage or for removal of the sequestrum should be made. It is a safe situation and one which affords access to the seat of disease with the smallest amount of destruction of the soft parts. The same rules as to opening the medulla by trephining apply here as elsewhere. When the disease affects the lower end of the shaft, the elbow joint is in great jeopardy because the diaphysis extends so far down as to be partially embraced by the capsule of the joint. Thus a suppurative arthritis of the elbow joint may occur and calls for the like treatment as when the same joint is affected by disease from the upper ends of the radius and ulna. In operating upon the disease situated at the lower epiphysis the incision should preferably be made upon the outer side of the limb so as to avoid the ulnar nerve. It must be remembered, moreover, that the musculo-spiral nerve winds around from the back to the front of the limb immediately under the supinator longus muscle and must therefore be very carefully protected. With care, however, both these nerves can be avoided, and, if necessary, incisions may be safely made on both the outer and the inner aspects of the limb. Total necrosis of the diaphysis of the humerus is very uncommon, but, if the disease should reach the medullary canal proper and extend from end to end of the bone, there may be patches of necrosis unequally distributed throughout its longitudinal extent. Muscular contraction and the weight of the limb together tend sometimes to produce a considerable shortening and twisting of the shaft during the process of repair, and if the upper epiphyseal cartilage is badly affected there may be a very considerable failure of growth, with resultant shortening of the limb. This circumstance, while much to be regretted, is not so troublesome to the patient as a similar shortening of the lower extremity, as a difference in the length of the two upper limbs is not particularly inconvenient to the patient.

Acute Osteomyelitis of the Os Innominatum.—Notwithstanding the fact that this large bone has no less than eight centres of ossification—primary and secondary—it is not by any means a frequent seat of acute osteomyelitis.

Yet it cannot be regarded as being immune, since occasionally cases are met with. One such case in which its pubic portion was affected is mentioned under the heading of "Multiple Foci" in this article. Another case occurred in the service of the author at the Sick Children's Hospital during the past winter. The history of this case is briefly as follows:

A lad, nine years of age, fell from a small wagon in which he was playing, and struck the crest of the ilium of the right side. No great pain was complained of at the time, and the lad, after a short interval, continued his play. He was able to be about for some days, but the part gradually became painful and fever developed. He was admitted to the Victoria Hospital for Sick Children some three weeks after the injury, and at that time there was marked swelling in the region of the right hip. The swelling was not in connection with the femur, and there was little or no interference with the mobility of the hip joint. The swelling, however, appeared to embrace both aspects of the body of the ilium, filling in the space between the great trochanter and the crest of the ilium on the outside and distinctly occupying the iliac fossa on the inside. On making the requisite incisions it was found that the periosteum of the iliac fossa was raised and the space beneath occupied by pus. The epiphysis of the crest of the ilium was entirely separated and the pus cavity extended to the subperiosteal space on the outside of the iliac bone. After drainage the case pursued a favorable course, and ended in recovery after the separation of a sequestrum from the inner aspect of the ilium.

This was clearly a case of osteomyelitis affecting the body of the ilium at its junction with the epiphysis of the crest. It did not extend along the body of the bone to the Y-shaped cartilage at the bottom of the acetabulum. If it had done so, doubtless the hip joint itself would have become affected, with very disastrous results.

It is thus apparent that acute osteomyelitis of the os innominatum may occur at the junction of any of the secondary centres of ossification with the main body of the bone. When the disease occurs at the bottom of the acetabulum where the Y-shaped cartilage is situated, it is quite apparent that the hip joint proper can scarcely by any possibility escape infection. Such cases are referred to by von Bruns and Honsell as "acute osteomyelitis of the hip joint." Through the Tuebingen Clinic they have reported the occurrence, during a period of forty years, of 106 cases of this affection, as compared with 500 cases of affection of the lower end of the femur. These 106 cases, however, include those affections of the upper end of the femur in which the hip joint becomes involved and in which the affection of the acetabulum is a secondary complication of the condition. Fifteen of the cases cited were credited to a traumatism in the shape of a blow, a fall, or a slip, and three were referred to cold. Under the heading of "Acute Osteomyelitis of the Femur" those cases of infection of the upper extremity of the femur have already been dealt with in this article. Von Bruns and Honsell, however, appear to include the neck and both trochanters with their epiphyseal foci when speaking of the upper end of the

femur, and describe numerous small multiple foci followed by the formation of scattered sequestra which they say are sometimes subsequently absorbed or may become encapsulated for several years. They describe also a deformity of the head, neck, and upper end of the shaft, giving rise to a bending of the bone as a whole, with marked shortening and deformity. Sometimes the head wastes and becomes absorbed, whereas in other instances an osteophytic growth takes place about its circumference, leading to that peculiar formation known as mushroom head.

The acetabulum of the os innominatum may be affected as a primary condition in the Y-shaped cartilage, or as a secondary condition from the spread of the disease through the joint cavity ensuing upon affection of the upper end of the femur. The cartilage and bone may be destroyed to a great extent, with perforation of the acetabulum, and varying degrees of destruction by necrosis of the ilium, ischium, or pubes may occur. Under these circumstances an abscess is very apt to form within the pelvis, thus eventuating in an exceedingly dangerous condition. Under drainage, however, recovery sometimes takes place, and there occurs around the acetabulum the development of very prolific osteophytic formations. The contraction of the muscles controlling the femur appears to act upon these bony products during the process of formation so as to press the acetabulum, as it were, upward upon the body of the ilium, thus leading to what is called "wandering" acetabulum. Not infrequently a complete bony ankylosis takes place between the acetabulum and the head of the femur, and usually, owing to muscular contractures, such ankylosis is in a very unfavorable position, calling subsequently for osteotomy or even sometimes for amputation.

In regard to treatment, those cases which survive the early stages of the disease must be treated according to the indications in each individual patient. If there is extensive disease of the upper end of the femur, however, and also of the acetabulum, resection of the joint is almost imperative, and in some cases nothing short of amputation gives any prospect of hope of recovery.

The Question of the Healing of Bone Cavities after Removal of Sequestra.

It must be borne in mind that in the vast majority of cases, even when the sequestrum removed has been extensive, and when a considerable cavity of the bone has resulted, nature is perfectly capable of looking after such cavities and bringing about a complete closure. The process may require many months, and occasionally, of course, a cavity remains open and discharging for years. The latter result, however, is quite the exception, and not the rule. But in order to give nature the best assistance possible, it is necessary to take advantage of the enormous activity which succeeds the subsidence of the acute inflam-

mation in the ensheathing periosteum and those remaining portions of bone which still retain their vitality, by removing the sequestrum as early as possible after its separation. Even in the largest bones, such as the femur and tibia, such separation may usually be counted upon to have occurred by about the twelfth to the fifteenth week. At all events, at this time it will have become quite certain which portions of the bone are destined to be ultimately sloughed off as sequestra, so that an operation may in almost every case be done within about four months of the onset of the disease. At this date the periosteum is extremely vascular, and even the compact bone is in a state of great activity as to its blood supply and as to the vigor and vitality of its bone cells. At this time there is no such ivory-like osteosclerosis around the cavity containing the sequestrum as develops if the sequestrum be allowed to remain in its coffin-like cavity for long months or years. Accordingly, if the operation be not too long delayed, nature's own physiological act may be pretty safely depended upon, not only to fill the cavity left by the removal of the sequestrum, but, as Ollier showed long ago, gradually to re-form the whole bone from end to end so that it ultimately becomes almost perfect in its outlines and in its power of sustaining weight.

Such being the facts in reference to the closure of bone cavities, there remain but few cases—and those mostly cases in which prompt operation has been neglected—in which any extraneous assistance in the closing of the bone cavity becomes necessary. Nevertheless, many surgeons have exerted their ingenuity in devising means by which the cavities in question might be closed with certainty and with greater celerity. Two principal methods have been adopted to bring about these desirable results: first, by operations devised to close the cavity by plastic and osteoplastic methods; and, secondly, by the insertion of various materials designed to fill the cavity temporarily and afford a transient scaffolding for the ultimate deposit of true bone. In regard to the first method, Esmarch endeavored to implant into the cavity flaps of the skin and soft tissues from its edges. Such flaps he endeavored to hold in position at the bottom and on the sides of the cavities by sutures or carefully adjusted pads. Neuber endeavored to secure the same result by nailing the flaps to the walls of the cavity. Luecke, Ollier, and Bier have advocated osteoplastic methods by which certain sections of the bone adjacent to the cavity are chiselled and sawn loose and afterward thrust down into the cavity to fill it partially. The success of such methods depends upon the accessibility of the locality where it is attempted, and the suitableness of the living bone adjacent to it. The greatest care must be observed to preserve the periosteum upon the transplanted portion intact, otherwise necrosis of this bone flap may follow and greatly add to the seriousness of the condition which it was intended to relieve by the operation. Such operations in the hands of their originators have unquestionably been of use, but they are operations requiring the exercise of a very unusual amount of skill

and judgment in their performance, and hence are not to be lightly undertaken, since, if success be not achieved, the condition left is worse than that which it was sought to remedy.

In regard to the second method, viz., the incorporation, into the cavity, of foreign substances, an almost infinite number of different materials have been recommended by as many operators. Among the substances recommended are: decalcified bone chips, the use of which has been strongly advocated by Senn and others; plaster; cement; copper amalgam; iodoform; blood-clot, with the use of which the name of Schede is inseparably connected; sterilized catgut, and other materials. Most of these have been tried and found wanting, and it is quite certain that, unless the cavity is so situated as to be rendered absolutely sterile, none of them holds out hopes of being beneficial. Probably the best results from treatment on this principle have been those obtained by the plan of von Mosetig-Moorhof. The substance which he recommends has the advantage of not only being sterile, but of having antiseptic properties and being ultimately capable of being absorbed and removed as the deposit of bone takes place. Reporting von Mosetig-Moorhof's work, Silbermark has credited him with successful treatment of 445 cavities occurring in 121 different individuals. The filling which he uses consists of: iodoform, 60 parts; spermaceti and oleum Sesami, of each 40 parts. This mixture is heated to 100° centigrade over a water-bath and then allowed to solidify under constant agitation so as to prevent the deposit of the heavy iodoform. The cavity to be treated is first thoroughly cleansed by curetting, and afterward it is swabbed out with a one-per-cent solution of formalin, then dried with swabs, and finally by a current of hot air. When thus carefully prepared, the cavity is completely filled with the melted mixture above referred to. The periosteum and skin are then sutured over it, without drainage, and a dressing is applied. Where everything progresses favorably the dressing is left undisturbed for from ten to fourteen days, by which time healing of the soft parts should have taken place. It is said that no iodoform intoxication has ever occurred, and that the cases almost invariably run an afebrile course. The hardened filling is gradually replaced by granulations, which subsequently become developed into new bone. The reports from the use of this treatment are certainly very encouraging, and, as the method seems to be based on sound physiological principles, it seems probable that this plan will in time replace others which have not been followed by such good results. Of course, whatever method be used in the way of the introduction of foreign material temporarily to close the cavity, should sepsis follow and suppuration occur, nothing remains but to remove the whole of the temporary filling and treat the cavity, for a time at least, by ordinary measures. When asepsis seems again possible, there can, of course, be no contrary indication to a repetition of the attempt by von Mosetig-Moorhof's plan.

Acute Epiphysitis.

Much that has been said in regard to acute osteomyelitis is equally applicable to acute epiphysitis. In their causation, in their nature, and in their onset the two conditions are precisely similar, and whatever differences exist are due to the different structure and anatomical relationship of the regions involved. Both are due to the development of a pyogenic focus in the immature tissue near the epiphyseal line.

Etiology.—In addition to the causes mentioned under osteomyelitis, tuberculous and syphilitic infections frequently give rise to inflammation of the epiphyses. The condition is especially common in hereditary syphilis, occurring, according to Steel, in eleven per cent of his cases, frequently in the first three months. In the septic cases the source of the contagion is usually not discoverable, but infection of the umbilical cord is said to account for some cases in the first weeks of infancy. For some reason which is not apparent, the epiphysis is most often involved in young children and infants; and the younger the child the greater seems to be the relative vulnerability of the epiphysis as compared with the diaphysis.

The epiphyses most commonly affected are those of the head of the humerus, the head of the tibia, and the upper and lower epiphyses of the femur.

Pathology.—The pathological condition, in all its essential features, is precisely similar to that which prevails in acute osteomyelitis. The fact, however, that the disease in this instance commences in the epiphysis itself has a very important bearing upon the ultimate result of the inflammation. It is obviously easier for the disease in its progress to reach the articular cavity than to spread through the epiphyseal line and reach the marrow of the diaphysis. In fact, so frequently does arthritis occur as a complication of acute epiphysitis that this is undoubtedly the disease which was described by Thomas Smith under the name of "acute arthritis of infants." In some joints, as the upper end of the femur and the upper ends of the radius and ulna, the inflamed epiphysis bears such a relation to the joint cavity that infection of the latter is a foregone conclusion. When arthritis develops, it is almost certain that in every case the inflammation will also extend across the epiphyseal line and lead to separation of the body of the epiphysis, which thus becomes a loose, freely-movable body within the suppurating cavity. In other words, the joint cavity, under these circumstances, practically extends as far as the epiphyseal cartilage. Occasionally the pus makes its way to the surface without causing separation of the epiphysis.

It should not, however, be forgotten that, as in the case of acute osteomyelitis, there are instances of acute epiphysitis in which the mild onset of the malady is such as to lead to irritation and hyperæmia of the epiphyses without any act-

ual suppuration. Should such a condition become chronic, as occasionally occurs, the irritation may be such as to lead to excessive growth of bone at the epiphyseal line and consequent lengthening of the limb rather than the contrary condition (Fig. 144).

In epiphysitis occurring as a result of hereditary syphilis, the early recognition of the location and cause of the lesion is of great importance. If mercurial treatment is promptly begun, amelioration follows within a fortnight. If the condition is not recognized, separation of the epiphysis may occur, with or without secondary pyogenic infection and suppuration.

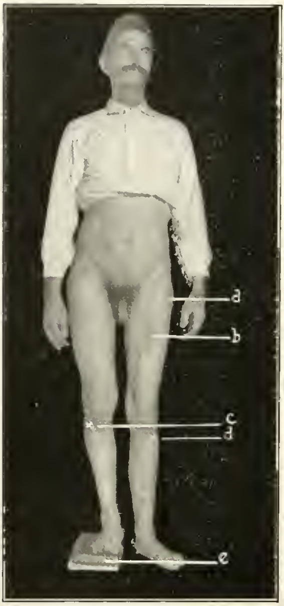


Fig. 144.—A Case Illustrating Excessive Growth of Bone from the Irritation of the Epiphyseal Cartilage from Chronic Inflammation in Its Neighborhood. *a*, Seat of a sinus leading to dead bone, the result of acute osteomyelitis of the epiphyseal line of the great trochanter; *b*, a sinus scar; *c*, level of right tibial tubercle; *d*, level of left tibial tubercle; *e*, books one and one-half inch thick. This represents the excessive length of the left femur. (Original.)

Prognosis.—Even when the joint is involved, recovery is often followed by surprisingly little loss of function. In the ultimate results the most serious feature is the deformity resulting from the interference with growth, to which reference was made in a previous section. When the disease occurs in a very young child this deformity may be very great, so much so that amputation may have to be considered as offering the best result.

Treatment.—The principles of treatment are the same as in osteomyelitis, viz., to expose and drain the infected focus as soon as possible. Promptness is no less important in this disease, and very great nicety and skill in diagnosis and operative treatment are required if the integrity of the joint is to be preserved. As has been said above, the most frequent occurrence of the disease is in very young infants, in whom the symptoms are almost entirely objective. In a case running an acute course it is quite certain that the joint will be involved before a diganosis and the appropriate treatment can be applied. One need not despair, however, of ultimately achieving a satisfactory result, even if the joint should become involved, since, as has been stated above, there is an amazing power of recuperation in the articular regions of young children.

It will usually be necessary, in order thoroughly to evacuate and drain the joint, to make two or more incisions, and these incisions should be made

with all the care in regard to surrounding structures that has been advised in the treatment of acute osteomyelitis. If, however, the symptoms are very profound and the depression great, it may become necessary to perform an amputation above the seat of the diseased joint. Such an operation, of course, is a severe tax on the resisting powers of young infants, but measures less heroic may not suffice to preserve life. In cases where the destruction of the epiphyseal cartilage leads to great deformity through failure of growth of the affected bone while its companion parallel bone continues to grow at a normal rate of speed, some special operation to correct the deformity may be required (Fig. 139). In the case, for example, of the diseased lower end of the tibia, with failure of growth, the continued growth of the fibula may crowd the foot to the tibial side of the limb (Fig. 140). Such a case may be remedied to a considerable extent by a resection of a suitable portion of the longer bone and forcibly twisting the foot back into a straight position in line with the main axis of the limb. Another method of treatment that has been advocated is to destroy the healthy cartilage of the parallel bone when it is quite certain that the disease has been such as completely to destroy the epiphyseal cartilage of the affected bone. This, however, should not be done until it is quite evident that the growing power of the affected epiphysis has been destroyed, since it is often quite surprising what recuperative power the epiphyseal cartilage has even after severe disease.

Chronic Osteomyelitis.

In the chronic diseases of bone, inflammation of the medulla is never the most prominent feature. It occurs only as a part of a more widely diffused process which involves chiefly the surrounding bone, but usually at some period the periosteum also. Chronic osteomyelitis thus affords a striking contrast to the acute form, in which not only the severity of the symptoms, but also the amount of involvement of the other structures, is chiefly determined by the intensity and extent of the inflammation in the medulla. The term is sometimes applied to the chronic inflammatory condition following an acute ostemyelitis and characterized by persistent sinuses leading down to the infected sequestra. Here, however, it is the cortical bone which is chiefly affected, and the medulla is involved only incidentally. This condition has already been described.

The various other chronic inflammations of bone in the .course of which the medulla is involved are described under their several headings. They include chronic osteitis, chronic abscess of bone, and tuberculous and syphilitic diseases of bone. In each of these the symptoms, diagnosis, and treatment depend upon the condition in the bone itself, and not upon the condition in the medulla.

There is a form of osteomyelitis, however, which is fairly entitled to the term "chronic," although in its main characteristics it presents the same pathological features as the acute form. In fact, it may be properly considered as being pathologically identical with acute osteomyelitis, but manifesting the symptoms in a very chronic form and extending over long periods of time, even to months or years. It differs from the acute form, however, in that it seldom leads to extensive necrosis, though a small necrotic area may be present. It also differs from the acute form in that it is associated with a chronic osteitis of the compact bone, and an osteoplastic periostitis which leads sometimes to a very considerable thickening of the shaft of the bone over a greater or less area (Fig. 142) and occasionally to a considerable increase in length (Fig. 144). Sometimes there occurs an accumulation of pus, which may vary from a few drops to several ounces. This pus may be confined to the region of the medulla, or it may form a distinctly circumscribed abscess in or near the epiphysis of the bone. This latter is the commonest form, and such abscesses are frequently known as "Brodie's abscess." It is not by any means unusual in these cases to elicit a history of acute osteomyelitis affecting one or more of the other bones, with or without necrosis, and such examples of chronic osteomyelitis are looked upon as late manifestations of the same condition which has lain dormant for a long period of time, sometimes reaching into many years, in the locality at which it ultimately manifests itself. When pus has formed, it is usual to find that the bone immediately around it is very much sclerosed and sometimes possesses an ivory-like density.

Symptoms.—Generally speaking, the constitutional symptoms of chronic osteomyelitis are not well marked, but after the disease has lain dormant for many months an acute condition may supervene, with symptoms not unlike those of the acute form. Fever, under these circumstances, may develop, and usually pain of an intermittent type and of a boring, gnawing, or aching character is developed. The pain is greatly increased by exercise, and, as in most other bone lesions, is apt to be much more marked at night. Tenderness on pressure can usually be elicited, and, even when this is absent, percussion of the bone will generally give rise to very considerable pain. The skin and other soft tissues are commonly unaffected unless the abscess has made its way out of the bone and is approaching the skin.

Diagnosis.—In the diagnosis care must be taken to eliminate syphilitic disease of the bone. This latter may be associated with pains at night, but these will subside rapidly under the administration of potassium iodide, and there will also be present other signs of syphilis. Suppuration also is infrequent in syphilitic disease, and the shaft of the bone is more frequently the seat of disease than in chronic osteomyelitis of the non-specific type.

Sometimes also the disease may be mistaken for osteo-sarcoma, and the possibility of an enlargement of the bone being due to chronic inflammatory

disease should not be lost sight of when an operation by amputation is under consideration, and it is a good practical rule to cut into any tumor in which the diagnosis is at all doubtful before proceeding to an irretrievable length.

Treatment.—While the inflammation is in the chronic stage and has not proceeded to the formation of abscesses, sometimes a considerable amount of relief can be obtained from the administration of potassium iodide, even if the disease may not have a syphilitic origin. When abscesses form, however, no time should be lost in evacuating them by free incision and by trephining or chiselling the bone where this may be necessary. The subsequent treatment is identical with that which has been described already in regard to the treatment of large cavities left after the removal of sequestra in the acute form of the disease. The prognosis as regards healing, however, is much less favorable in this form, and the further treatment of such chronic cases will be taken up under the heading of "Brodie's Abscess."

NECROSIS.

Phosphorus necrosis is a disease affecting most often the lower, but sometimes the upper, jaw. As the name implies, it is due to the action of phosphorus, but the precise manner in which the necrosis is brought about is not, so far, quite clear. It is confined to the workers in yellow phosphorus, and is not caused by the red or amorphous variety. The substitution of red for yellow phosphorus in some commercial processes, and the increased care taken to protect the workmen from its deleterious action, have greatly reduced the prevalence of the dissease, but it is still common in some parts of France where the making of matches is carried on in the dwelling-houses.

Some observers regard the first step in the disease as due to the action of phosphorus fumes on the peridental membrane. Mears regards the disease as a chronic phosphorus toxæmia with a local irritation of the gums caused by decayed teeth and tartar. He thinks that the phosphorus enters the system partly by inhalation and partly in particles taken with the food. William Hutchison mentions a case in which the prolonged medicinal use of phosphorus was followed by a typical necrosis. François Armand states that the systems of match-makers become so impregnated with phosphorus that the odor is perceptible in all their excretions. Albuminuria is present in a large percentage of those who are much exposed.

The local symptoms first appear about the root of a decaying tooth, causing pain which is not relieved when the tooth is extracted. Inflammation of the periosteum of the jaw follows, the irritation causing the formation of new bone on the surface of the old. Then, apparently, as the result of a secondary infection, suppuration occurs between the new bone and the old or sometimes

between the new bone and the periosteum. The underlying bone thus separated from its periosteum dies, and, as the process extends, the whole jaw may become necrotic. The duration of the disease, from the beginning of the symptoms is given by Hueckel as fourteen months for the lower and thirty-three for the upper jaw.

Treatment.—Prophylactic measures have done much to prevent the disease. These consist of: The substitution of red for yellow phosphorus whenever possible; the careful ventilation of the workshops; the substitution of match-making machinery for manual labor; scrupulous cleanliness; thorough cleansing of the hands before eating; careful attention to the gums and teeth, and the discontinuance of work whenever any irritation of the gums appears. The vapor of turpentine is supposed to neutralize the fumes of phosphorus and probably serves as a carrier of oxygen by which the phosphorus is oxidized and rendered harmless. When the disease is established, removal of the affected bone is probably the best treatment. If the periosteum is preserved, at least partial regeneration will occur. The process of regeneration of bone and of separation of the part which is diseased may be facilitated by occasional progressive separation of the periosteum by means of a suitable instrument, as was so successfully practised by the late Prof. James R. Wood, of New York, Bellevue Hospital.

CIRCUMSCRIBED ABSCESS OF BONE

(Brodie's Abscess.)

Circumscribed abscess of bone is in the great majority of cases a late result of acute osteomyelitis, and it is by some writers included under the heading of chronic osteomyelitis. But it is characterized by such definite symptoms and runs such a definite course that it is best treated of in a section by itself.

Examples of a chronic form have been given under the heading of "Chronic Osteomyelitis" in this work, and the condition has also been alluded to under the heading of "Postfebrile Inflammatory Disease of Bones," but the term "Brodie's abscess" has stood for this condition so long in standard text-books on surgery that a résumé of the condition which it describes appears to be called for in a complete treatise on inflammatory diseases of bone.

Many writers have given their attention to this condition, and many diverse views are held regarding it. Alexis Thomson, of Edinburgh, has quite recently analyzed the works of older writers, and has added much to our knowledge of the condition by bacteriological and clinical studies. His article has been freely made use of in the following account of the condition.

Etiology.—Nearly always there is a history of acute osteomyelitis, which

generally has occurred many years previously. The cause of the abscess is probably a pyogenic focus which has become encapsuled during the reparative process following the acute disease and has remained latent for a variable period thereafter. Out of 145 cases collected by Thomson, in which the early history was available, there had been osteomyelitis in childhood in 122. It is possible that in some of the others a mild attack of this disease had passed unrecognized or had been forgotten. There seemed to be a relationship between the severity of the primary attack and the length of the succeeding latent period. This averaged eleven years after the milder attacks and eighteen years in those which had caused suppuration and necrosis. The termination of the latent stage is brought about by causes similar to those which induce an attack of osteomyelitis—slight traumata, fatigue, exposure, etc.

The bone affected most often is the tibia, as the following statistics, quoted from Thomson's article, show:

In 161 cases of abscess the situation was as follows:

Tibia, upper end	63
" lower end	42
" upper and lower ends	1
" middle third shaft	2
" level not stated	11
	119
Femur, lower end	18
Humerus	18
Radius	4
Ulna	2
	161

Bacteriology.—As one would expect, the bacteria found in chronic abscess are the same as those which give rise to acute osteomyelitis. The Staphylococcus pyogenes aureus in pure culture is the most frequent. In cases following typhoid infection the Bacillus typhosus is found alone or with the Staphylococcus. Thomson reports a case from which a pure culture of the Staphylococcus pyogenes albus was obtained.

Pathology.—Thomson describes the pathological anatomy as found in his cases in three stages:

1. The Latent Stage.—In this stage there is a cavity in the bone filled with serum in which no tissue elements are found and in which the usual staining methods fail to reveal the presence of micro-organisms. In the case described the cavity was about 2 cm. in diameter. It was lined with a membrane whose outer layer was closely attached to the bone and was indistinguishable from the periosteum of young bone. At a little distance there was an area of sclerosed bone entirely surrounding the cavity and occluding the medullary canal. This sclerosed bone is usually extremely hard and dense.

2. The Mature Stage.—The cavity contains pus, tissue elements, clumps of bacteria, and occasionally small sequestra. The lining membrane is of granu-

FIG. 145.—Section of Right Tibia, showing an Enormous Chronic Abscess in its Upper End—Brodie's Abscess. (From Alexis Thomson, in *Edinburgh Medical Journal*, New Series, vol. xix.)

lation tissue. There is a feeble attempt at new bone formation, but this is more than counterbalanced by the erosion which takes place and which gradually

increases the size of the cavity. The erosion may be equal in all directions, but more often irregular diverticula are formed. The area of densely sclerosed bone offers considerable resistance to the process of erosion, and the enlargement of the cavity is slow. As the surface of the shaft is approached, the irritation of the periosteum leads to the formation of new bone, giving rise to a circumscribed thickening. But sooner or later, if the joint escapes, the new bone is eroded and the pus makes its way through the soft tissues to the surface. Toward the articular cartilage there is not the same protection by new-formed bone; and diverticula in that direction are very apt to penetrate into the joint and set up a septic arthritis. Occasionally the neighboring bone is not sclerosed, and extension of the cavity is rapid. In one of Thomson's specimens the surrounding bone was cancellous throughout, and perforation into the joint occurred within four months of the time when first symptoms appeard.

3. The Third Stage.—When the abscess ruptures spontaneously on the surface of the limb, no further erosion of the bone occurs, nor does the cavity in it tend to heal. A chronically discharging sinus remains which does not necessarily interfere greatly with the use of the limb. In the Royal College of Surgeons, Edinburgh, there is a specimen of a tibia in the upper end of which there is a cavity of the capacity of 16½ oz. (referred to by Thomson; presented by Prof. James Russell). (Fig. 145.) The patient went about as usual for ten or more years, controlling the escape of pus by means of a wooden plug surrounded by tow and thrust into the aperture, which measured a little more than an inch in diameter.

In ordinary cases all the stages are long-drawn-out. The latent period, as has been stated, is usually of many years' duration. The mature stage, the stage of extension and of erosion of bone, may last for many months before the surface of the bone is reached. The third stage, the stage of chronic discharge of pus, persists throughout the life of the patient unless relieved by operation.

Symptoms. During the latent stage there are none. In the mature stage, pain, at first indefinite, afterward referred to the end of the bone, is the most prominent symptom. It is of a boring or gnawing character, and, as in other inflammations of bone, is usually worse at night. In the lower extremity it is also made worse by walking or long standing. The pain is not continuous, but is variable and intermittent, sometimes being absent for weeks or months, to return again for similar periods. As the disease progresses, the painful periods become of longer duration and recur after shorter intervals, till finally the pain is continuous. Thomson attributes the pain to the increasing pressure of the confined pus, and considers that, when the erosion of bone proceeds as rapidly as the formation of pus, the pressure is relieved and the pain ceases, to return again when the balance between the processes is disturbed. At a later stage the pain is probably due in part to periostitis. There may be pain

in the neighboring joint. Tenderness is found over the affected area and is elicited most easily by percussion. It becomes more marked as the disease approaches the surface. Constitutional symptoms are slight or wanting, and septicæmia, pyæmia, and thrombosis rarely occur. Circumscribed enlargement of the bone has already been referred to. Œdema, with pitting of the soft tissues, and dusky redness of the skin, are late symptoms, and point to the progress of the affection toward the surface, seeking spontaneous evacuation.

Diagnosis from Sarcoma.—The diagnosis from other painful affections of the ends of the long bones is not easy, and sometimes can be made only during operation. A history of previous osteomyelitis is suggestive. The growing abscess is always accompanied by osteitis, and, when it approaches the surface, by periostitis. In the early part of the mature stage it is distinguished from periostitis by the deep-seated pain with comparatively little tenderness and by the absence of thickening of the periosteum or shaft. The joint also may give warning of approaching danger before it is actually invaded. "Intermittent attacks of inflammation of a neighboring joint, without other apparent cause, are very suggestive of abscess" (Walsham).

In the later stage, when rapid circumscribed thickening of the shaft is taking place, sarcoma may be suspected. The rate of growth does not help in the diagnosis. A skiagraph may afford some information. If there is much sclerosis the shadow is dense and is uniform throughout. This serves to exclude conditions such as gumma, tubercle, and sarcoma, which are not accompanied by sclerosis of the surrounding bone. A well-defined lighter area in the centre of a dark shadow (Fig. 138), and showing, above and below the lighter area, the shadow of the sclerosed bone obliterating the medullary canal, is very characteristic of abscess (Thomson).

Treatment.—The treatment consists in reflecting the soft parts and periosteum and chiselling away the bone so as to leave a cavity whose walls slope outward toward the surface, in order that the space may be partly obliterated by the falling in of the soft parts. All infected material, including the lining membrane or granulation tissue, is scraped away, and a thorough mechanical cleansing and disinfection of the part are carried out. If this be done, there seems to be no necessity for swabbing out the cavity with pure carbolic acid, as is sometimes recommended.

The question of subsequent treatment of the cavity has already been dealt with in a former portion of this article and need not again be specially referred to. It resolves itself again into the question of allowing the cavity to heal from the bottom by granulation, encouraged by an antiseptic packing, which in the vast majority of cases will bring about complete healing; or in attempting some of the many plastic or osteoplastic methods of closing the cavity which have been recommended; or of allowing the cavity to fill up with blood-clot, which certainly may be done in the smaller cavities; or of filling the cavity with Von Mosetig's

wax or some of the other foreign bodies which are recommended by various authors as a temporary scaffolding for the growth of bone tissue.

The following is a case of Brodie's abscess in which an attack of acute osteomyelitis with a discharge of pus seems to have terminated by a spontaneous death of the colonies of staphylococci which caused the disease. After the death of the germs a large quantity of pus seems to have been left behind and become encapsuled, remaining comparatively innocuous in the end of the bone for a great number of years. The location of the disease, also, viz., the upper end of the femur, is one which is apparently extremely rare, as no similar location is noted in Thomson's or Gross' statistics.

F. R., a farmer, aged 39, was admitted to the author's service in the Toronto General Hospital on December 21st, 1905. He gave a history as follows: Nineteen years ago, when the patient was about 20 years of age, he slipped into a hole at a barn-raising and grazed the great trochanter of his left femur against a sharp edge of a square timber. No fracture was sustained, and though the injury was painful he did not stop work, nor did he experience any great pain or disability for some weeks. Then febrile symptoms with pain at night set in and his general health became affected. The part was swollen over the great trochanter, and was subsequently opened by a surgeon. The fluid evacuated was distinctly purulent, and was evidently connected with disease of the shaft adjacent to the epiphysis of the great trochanter, which at that period would scarcely be ossifically united to the shaft of the bone. After a time the discharge subsided and the skin wound healed. The affected leg, however, always appeared to be slightly weaker than its fellow, and has been the seat of slight occasional pains, though it did not materially incapacitate him. About three years ago he had an attack which lasted a few days and then again subsided. About six months before admission, however, the hip began to trouble him greatly. He was working hard harvesting his grain and got a thorough wetting. Pain in the hip developed very severely, and he was obliged to relinquish work. He described the pain as aching in character, much worse at night, and also worse after walking. There was, however, no suppuration, and a few weeks later he was able to do some fall ploughing. This condition continued with fluctuations, but without active and evident suppuration, from August till December, 1905, a matter of some five months. On examination, when he was admitted to the hospital, the condition very strongly suggested the possibility of sarcoma, but an x-ray examination revealed a considerable sclerosis of the bone with thickening of the periosteum, and without any of the lighter degrees of shade which are characteristic of sarcomatous disease. Moreover, the part had a rugged, well-defined feel to the hand, which is usually absent in neoplasms of bone. A chronic abscess of bone (Brodie's abscess) was diagnosed and an incision was made down to the great trochanter. A small opening was found in its outer aspect which led to a very large cavity occupying the upper fifth of the shaft, the whole of the great trochanter, and also the neck of the bone apparently as far as its original epiphyseal line. It measured about four inches in longitudinal diameter by about one inch and a half in a transverse direction. At this stage, however, there was no active involvement of the hip joint, though there was very great limitation of movement of the femur, the limb being adducted and rotated inward as in cases

of advanced hip-joint disease. The contents of the cavity had the appearance of pus from which nearly all the liquor puris had been extracted. It did not look like the cheesy matter of tuberculous disease, nor was it like the gummatous material of a syphilitic lesion. It was clearly the old, partially inspissated pus containing no formed cellular elements, but having some small irregularly shaped sequestra, few of which were more than one-half inch in diameter. The wall of the abscess had no such distinctly defined membrane as Thomson describes in these cases, but was formed of densely sclerosed bone. The whole of the cavity was cleaned out and its diverticula carefully followed. The cavity was then packed with gauze and a large dressing applied.

The patient's temperature before the operation had usually risen in the evening to 101° or 102° F., and this condition persisted after the operation. The relief to pain also was not nearly so marked as had been anticipated, and altogether the patient made very poor progress. Though a bacteriological examination of the dry pus was negative, the whole cavity soon showed evidence of a revival of the activity of the staphylococcus germs, and suppuration was pronounced. The patient's general condition was extremely low, and very little local reaction in the way of healing seemed to be present. It became evident very shortly that the disease had extended through the head of the bone into the hip joint, and in the course of a few weeks a pathological dislocation of the femur took place. The patient absolutely refused to entertain the idea of resection or amputation of the limb, which was strongly advised. He returned to his home June 6th, 1906. At that time various sinuses were present, from which pus discharged, and the femur was clearly dislocated upon the dorsum ilii.

NON-INFLAMMATORY AFFECTIONS OF BONES.

By ROSWELL PARK, M.D., Buffalo, N. Y.

THE internal architecture of the bones must have interest for all, even the surgeon, since upon it depend their strength and density, *i.e.*, their *reliability*, while the architectural type upon which they are built up has afforded great aid to the studies both of the architect and of the structural engineer. No more complete picture of maximum of structural power with minimum of material can be found in nature than in the structure, for instance, of the neck of the femur, the os calcis, the skull, and, in fact, every bone of the body. Thus, by careful study of structure there has been evolved, from the chaos which seemed to pervade every spongy bone, a beautiful mathematical and mechanical design of development, which can only bring out expressions of the highest admiration. Nowhere is more beautifully illustrated the adaptation of physical peculiarities to physical needs. Hermann Meyer, in 1867, was perhaps the first to call attention to this fact, while his friend Culmann, who was professor of physics in Zurich, studying Meyer's preparations, came to the conclusion that the internal structure of the bone was built up for a definite purpose and upon definite lines, which the mathematicians, in their graphic and substantial way of looking at things, call "trajectories." Julius Wolff introduced the method of making thin bone sections with a saw and thus studying their structure, and Wilhelm Roux finally subjected the whole matter to a very close analytical study and definitely demonstrated the lines taken by these trajectories.

Thus, for instance, in a comparative study of the architectural structure of the neck of the femur, it can be seen that a very definite plan seems to be followed, and that the lines of calcified, *i.e.*, strengthened, tissue are laid down along the lines of force where greatest strength is needed, and that thus the means is beautifully adapted to the end. Careful studies of this subject, with elaborate drawings, may be found in the literature of the subject (Schuchardt and Wolff) and may be consulted by those interested. Just as Leonardo da Vinci seems to have made a most careful study of spirals, taking for his model some of the shells, and making their lines serve for the spirals of some of his most important buildings, so one may take the lines seen in the internal structure of some of the spongy bones, which apparently are so purposeless, and, by tracing them carefully, realize that this apparently casual, purposeless structure is built up on the most beautiful type of structural strength.

Plates XX, XXI, and XXII, taken from Wolff's large work, illustrate the facts herein briefly mentioned.

As a result of Wolff's studies he formulated the so-called law, which is known as "Wolff's Law of the Transformation of Bone," and which may be condensed into the following terms: *Every smallest particle of bone is prepared at any moment, when changes occur in other tissues or elsewhere in the bone by which it has been made superfluous, to disappear; while, conversely, at any moment when at any given point in bone any new particle of bone material is needed, it is quickly furnished in response to this demand and to the static necessities of the case.* This is of importance in connection with what has been elsewhere stated about the varieties of bone (*vide* below), since it implies, what is throughout this article emphasized, that *bone is a tissue and, like other tissues, changes in response to conditions of its nutrition and its environment.*

This also, in view of all this interesting material, would be a most timely opportunity for discussing the question of regeneration of bone, with which again the subject of this article only has indirectly to do, and which, therefore, must also be laid aside. It cannot be quite dismissed, however, without some allusion being made to the memorable services of Ollier, who has done so much in the experimental demonstration of the possibilities of regeneration in bone, and whose three volumes on the subject are replete with most interesting observations.* The manner in which bone grows, and especially the way in which it repairs its own injuries, must be well appreciated, not alone by him who seeks only an explanation of non-inflammatory bone affections, but especially by the surgeon who concerns himself with all kinds of bone surgery, including the various osteoplastic resections.

It is interesting and significant that, the lower we go in the animal scale, the greater are the powers of regeneration, this being true of tissue of all varieties. Thus, many of the crustacea and other orders have the power, for instance, of reproducing an entire limb, including all its component tissues. Passing upward, we see this power diminish quite rapidly until, among the quadrupeds, as among the birds, powers of regeneration become extremely limited; while, when we come to man, at the top of the scale, his abilities in this direction are reduced to such an extent that even the reproduction of a finger nail is often more than can be expected. Nevertheless, in his bones he retains much of his original capacity for renewal, and, it is even possible, under certain circumstances, and especially when the periosteum has been preserved, to reproduce almost an entire new bone.

An ultimate analysis of the actual causes of non-inflammatory as well as other diseases of the bones (and, for that matter, of other tissues as well) will permit a division of the same, as well as their more rational consideration, under the following classification:

*Ollier: "Traité de Régénération des Os."

EXPLANATION OF PLATE XX.

Fig. 1.—From an Amputation Stump. Atrophy and disappearance of structure no longer needed. (Wolff.)

Fig. 2.—Leg-Amputation Stump. Atrophy with osteophytic fusion at bone ends. (Wolff.)

Fig. 3, A, represents Ward's scheme of the architecture of the upper end of the femur.* In the smaller diagram, B, is represented an old-fashioned crane, in which the directions of the different forces brought into play when a weight is lifted are indicated by the same letters as those affixed to the accompanying larger diagram (A). Ward's view that the same mechanical principles are applied in the crane and in the upper end of the femur is not accepted in its entirety by Wolff.

Figs. 4 and 5 illustrate the architecture of the upper end of the femur.

*F. O. Ward: "Outlines of Human Osteology," London, 1838.

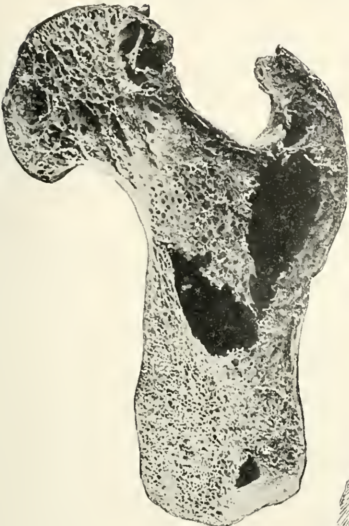


FIG. 1.

FIG. 2.

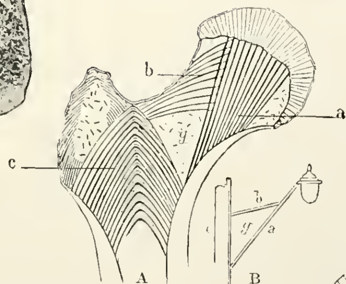


FIG. 3.

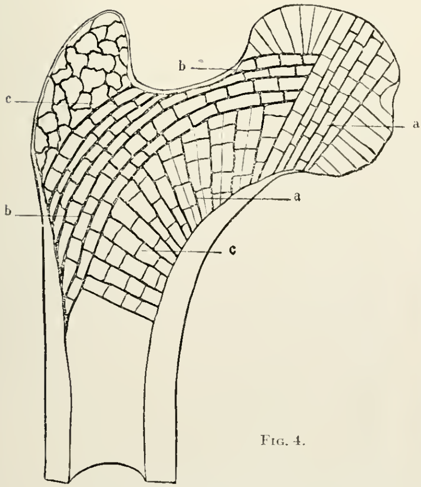


FIG. 4.

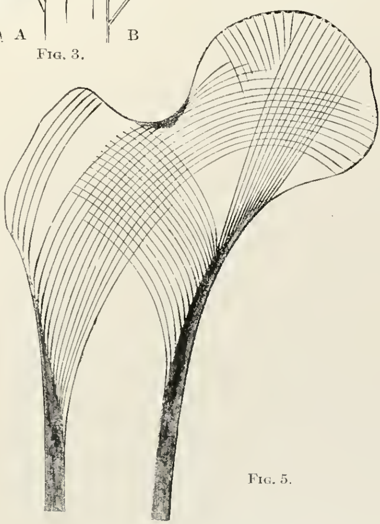


FIG. 5.

ARCHITECTURE OF THE UPPER END OF THE FEMUR; ALTERATIONS IN A BONE AFTER ITS NORMAL FUNCTION HAS CEASED.

(From Wolff's "Gesetz der Transformation der Knochen.")

A. Nutritional.

B. Parasitic (considered elsewhere).

Each of these may be either congenital or acquired. The limits of this article entail only a consideration of the first of these, since it deals only with non-inflammatory affections of the bones. For present purposes, therefore, we shall deal with them as comprising the congenital and the acquired forms.

An even better working classification of the nutritional defects, for the purposes of study, will be the following:

1. **Congenital.**—This must include the various types of arrest of development, as well as the contrary, and might include a consideration of all sorts of defects and deformities, from any of the thinkable embryonal defects, such as absence of an entire extremity, etc., to forms of gigantism which pertain to a single digit or involve an entire limb, or to expressions of dicrotism which are to be regarded as atavistic, evincing a tendency to reversion to earlier embryonal forms. There is no room here, however, for scientific discussions concerning prenatal pathology, nor the so-called "laws" which seem to govern the development of the embryo. They constitute most interesting topics in biopathology, but are dealt with by the surgeon rather as expressions of defects or deformities which may permit or require mechanical treatment, and which to the orthopedist, as such, scarcely appear to be even expressions of disease but rather problems in mechanics.

Our principal concern must be with acquired affections, which may be thus divided:

2. **Acquired.**—

- A. Physiological.
  - (*a*) Developmental.
  - (*b*) From disuse.
  - (*c*) Senile.
  - (*d*) Nutritional.
- B. Pathological.
  - (*a*) Results of injury.
  - (*b*) Results of previous disease. { Active and infectious, chronic of any type.
  - (*c*) Results of continuous pressure. { Chinese women's feet, Indian flat heads, tumors, aneurisms, results of continued muscle spasm, etc.
  - (*d*) Irregular, slow, neurotrophic, and unclassified forms.

Such a classification will at least conduce to a clearer analysis and comprehension, even if it does not assist in clinical study; though it must be said that clinically these expressions may be so complicated or combined that it may be difficult to assign a given case to its proper position in the list.

The general purposes of the osseous system are triple:

First.—Locomotor, inasmuch as it furnishes both framework and support, and in nearly every bone levers as well, which, being moved by various muscles,

are made to serve a definite mechanical purpose. In the various bones and their muscular origins or insertions we may find numerous illustrations of levers of all three orders.

Second.—Protective, in that it furnishes permanent and rigid enclosure for important internal organs.

Third.—Supportive, in that by it at all times are maintained the normal shape and relations of the component parts of the body.

In man the rigid and inflexible supports are mainly internal, as in the extremities, or, numerically less frequently, superficial, as in the case of the cranium, the thorax, and the pelvis, where external protection is most needed. In the lower animals, on the other hand, it suffices, in at least many genera, to have their rigid support on the exterior, where it serves as well for protection, this being conspicuous in animals of all varieties which have bony or cartilaginous shells, not the least of whose important functions is to protect them from becoming the prey of other animals. Gradually, and through processes well known to the evolutionist, the exoskeleton of the lower forms of life has been converted into the endoskeleton of the quadrumana, according to their needs. In every instance, however, the composition of this skeletal structure, when of bone, is in its essential respects the same, since it derives its mechanical strength from the presence of calcium salts. In every instance, too, it is developmental, since in its beginning every normal bone is soft. This means that in certain tissues and locations there occurs a deposition of calcium salts, corresponding in inanimate nature to petrifaction. *None the less, bone is a tissue,* and this fact must be always emphasized, since it seems very hard for the average student so to regard it, especially since he usually begins his studies upon the prepared skeleton, and because this alone supplies the reason for the fact that *in bone, hard as it is, there may occur any and practically every pathological process which is seen in any other tissue,* from most acute infection down to the slowest of pathological and nutritional changes, from the so-called trophic influences to the most active parasitic invasion, either by microscopic or by grosser parasites. In fact, *let it be remembered that in bone may be found the counterpart of every morbid process seen elsewhere. Unless this fact is ever kept clearly in mind there can be no clear notions of bone disease.* Let us add to this that the same statement is true also of the degenerative process, which in bone differs in no essential respect from the same process taking place elsewhere.

General Dwarfing, Micromanosomia, and Cretinism.

Dwarfing of the entire skeleton is a condition occasionally met with, to a degree so pronounced that its subjects have often assumed dime-museum notoriety. Its most pronounced instances are noted in history, *e.g.,* that of "Tom Thumb" and others of the same kind. On the other hand, some particular

EXPLANATION OF PLATE XXI.

FIGS. 1, 2, and 3 Illustrate the Internal Architecture of the Upper End of the Femur. (From Wolff, "Gesetz der Transformation der Knochen.")

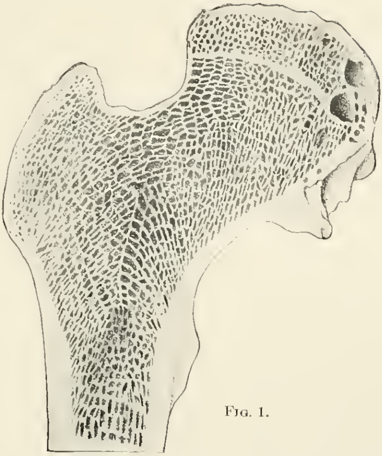


FIG. 1.

FIG. 2.

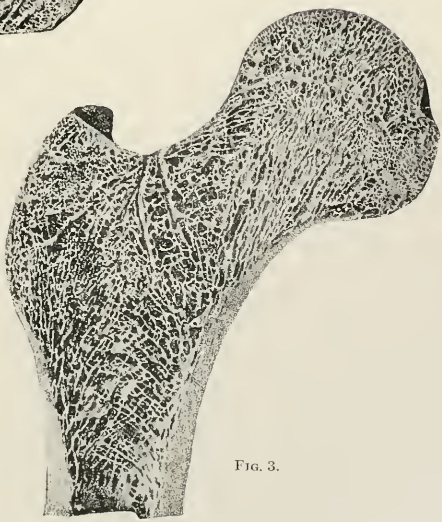


FIG. 3.

LONGITUDINAL SECTIONS OF UPPER END OF HUMAN FEMUR.

(From Wolff's "Gesetz der Transformation der Knochen.")

portion of the skeleton may suffer, apparently by itself and without others being involved. While the condition is usually brought about by insufficiency of energy of fœtal development, or by too early calcification, it is hard to account for those cases in which only one limb, for instance, appears affected. When the entire skeleton is not involved it is the flat bones which are particularly affected. In many of the so-called dwarfs the cartilaginous structures are often found soft, or the reverse may obtain, and they may have all been thus prematurely stiffened up in such a way as to prevent future growth. Premature union of the cranial sutures (synostosis), or of those of the pelvis, leads to distinct alterations of form and type, while serious conditions develop in the parts contained within. Thus, in the skull synostosis may lead to microcephalism, with its failure of brain development and consequent imbecility. It is a notable fact that most dwarfs are as much dwarfed in mind as in body. An unsymmetrical skull is spoken of as plagiocephalism, as when the sutures of one side are prematurely united. When this occurs across the transverse diameter of the skull the latter is shortened and we have dolichocephalism; when in the spheno-parietal sutures, we have clinocephalism, *i.e.*, saddle-shaped skull; and when along the spheno-frontal sutures, leptocephalism. Shortening of the antero-posterior diameter is called brachiocephalism; and that of the transverse diameter, in general, dolichocephalism. When the posterior portions of the skull are undeveloped it is known as oxycephalism, while an irregular, round head is known as trochocephalism. Finally, the condition of platycephalism, or flat head, is seen, especially in rickets and osteomalacia. Here the vertex approaches nearer to the skull base than normal.


FIG. 116.—Illustrating Effect of Thyroidectomy, on Sheep, in Producing Condition Analogous to Cretinism. (von Eiselsberg, *Archiv f. klin. Chir.*, Bd. 49, 1895.)

Similar deformities occur in the pelvis and produce well-known difficulties in parturition, while, in the spinal column, they cause rotary lateral curvatures, free from those inflammatory expressions which characterize spondylitis.

The limitations in growth which accompany or are a part of so-called *cretinism* appear in earliest youth, and are accompanied by more or less distinctive evidences of myxœdema, imbecility, and defective development of the genitals, and are referred to some more or less vague disturbance in the functions of the thyroid. It is enough here, perhaps, to call attention to this fact as another illustration of that mysterious connection between the genital glands, the thyroid, and general nutrition. A similar condition may be produced experimentally by feeding young animals for a long time with thyroid extract. (See Fig. 146.)

We have next to consider formally the general subjects of atrophy and hypertrophy of bone. Here again, and of each of them, it may be said that they are best to be studied in their acquired form under the head of

A. Physiological. (*a*) Developmental,
(*b*) Nutritional.
(*c*) The atrophy of disuse.
(*d*) Senile.

B. Pathological. (*a*) Traumatic.
(*b*) The result of pressure from without in consequence of extrinsic disease.
(*c*) The result of intrinsic disease, acute or chronic.

Atrophy of Bone.

Between mere arrest of growth and atrophy in its true pathological sense, there may be little, if any, apparent external difference, while the two processes may, nevertheless, be widely variant. Limiting one's self here in the use of the term "atrophy" to those conditions in which there has been absolute disappearance of bony tissue once present, one may liken it very much to the atrophy of muscle which notably takes place under conditions of enforced rest and often of various disease processes. Thus, in bone there are the actual atrophy of disuse and that of old age, as well as that of disease, with resulting conditions, which are very similar, yet not identical. It was, perhaps, Curling who, in 1837, first made a distinction between the conditions which he called *concentric* and *excentric* atrophy of bone, the former depending mainly on local causes such as consecutive dislocation, caries, inflammations resulting from gunshot fractures, etc. Under this head he included also the bone end of an amputation stump, as well as the atrophied bones of ankylosed limbs. He spoke of functional inertia and the influences of the central nervous system by which, for instance, in paralytics healing of fractures is retarded; and he showed how shutting off of circulation, at least in part, might have the same result upon a bone fragment that it has upon the softer organs and viscera; maintaining that, when the Haversian canals were so inextensible, nutritive supply should not be main-

EXPLANATION OF PLATE XXII.

Fig. 1.—Metacarpal (of a Young Calf) which had been Constricted by a Ring. (Wolff.)

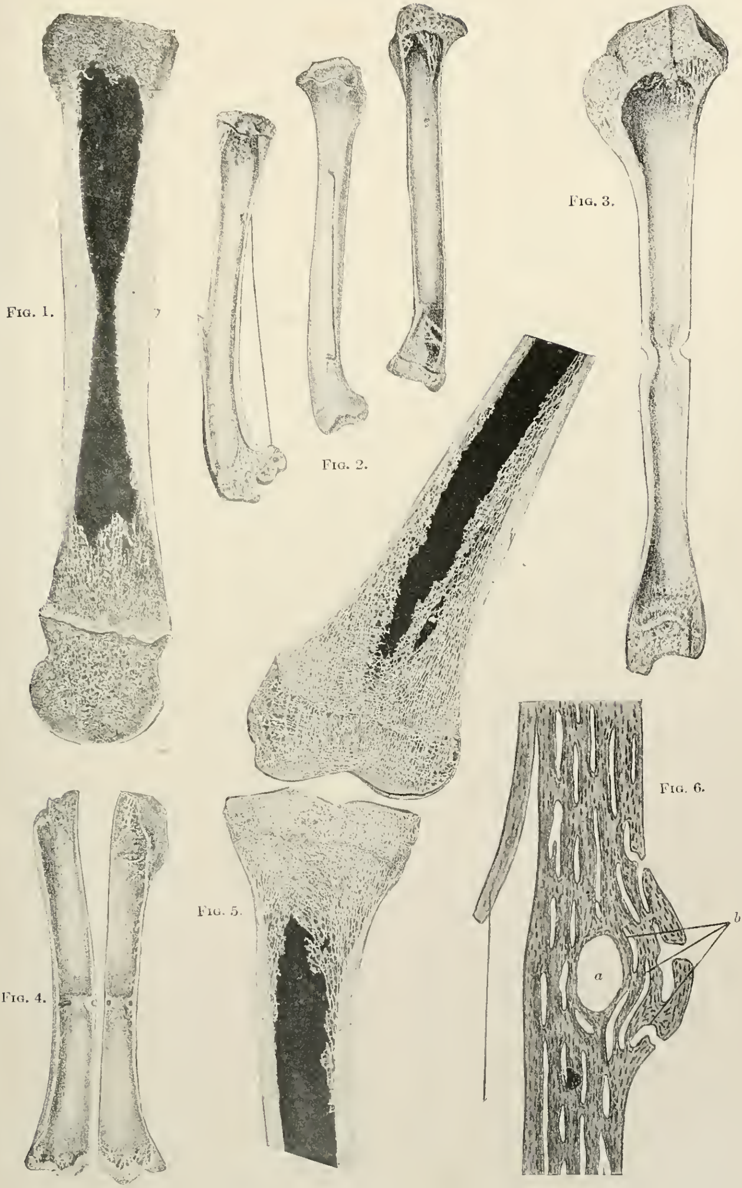
Fig. 2.—Experimental Exposure of Bone with Insertion of Wire. Curvature of bone as it grew. (Three stages represented.) (Wolff.)

Fig. 3.—Constriction Due to a Ring Placed Around Growing Bone. (Wolff.)

Fig. 4.—Ring Experiment upon a Growing Femur; Inclusion of Ring in the Developing Bone. (Wolff.)

Fig. 5.—Changes in the Leg of a Case of Genu Valgum (From Billroth's Clinic.) Total rearrangement of internal architecture and marrow canal, in accordance with change in lines of force. (Wolff.)

Fig. 6.—Similar Experiment. *a*, Site of ring; *b*, *c*, periosteal development. (Wolff.)



CHANGES IN THE FORM OF A LONG BONE DUE TO FORCES APPLIED FROM WITHOUT.

(From Wolff's "Gesetz der Transformation der Knochen.")

tained in a loosened fragment. *Excentric atrophy* he considered mainly in connection with osteomalacia as a generalized process with a constitutional cause.

But little later Malgaigne directed attention to the disappearance of the alveolar process which is deprived of its teeth, and to such atrophying processes as thinning of cranial bones after trephining, and of the bones about the hip after old and unreduced dislocations. Bonnet at this time also called attention to the fact that chronic joint affections were always characterized by more or less atrophy of the component parts of the affected articulations.

About the middle of the previous century, in the French Society of Surgery, the question was raised by a number of its members as to whether it was impossible to have a physiological elongation in an amputation stump of the end of a long bone, independently of any failure in operative technique; and for some years this and similar questions occupied much of the attention of the society. Members were seeking a cause for the fact that in young subjects the bone frequently grows through the soft parts of the stump, perforates them, and appears exposed at its end. By Marjolin this was attributed to a certain degree of ostitis propagated from the upper epiphysis, but others held it to be due to a relatively greater growth due to osteophytes developed upon the lower extremity of the amputated bone. Humphrey in his great work upon the skeleton, in 1858, called attention to the results of various bone diseases, saying: "If a limb be not used the bones usually waste. . . . In some the bones are cleared of their cancelli and reduced to a mere porous shell, the size remaining unaltered. In others they become much reduced in circumference. In a third class the bones are small and are also light and porous. In a case, recorded by Larrey, of a man who died forty-one years after amputation of the arm near the shoulder, the scapula was as thin as paper, and the clavicle no thicker than that of an infant. I am not aware that a bone is ever reduced in length as a consequence of atrophy. If a part be disused by reason of paralysis or other causes the bones may fail to attain their proper length; but, having attained it, I do not know that they ever lose it."

Fig. 147.—Concentric Atrophy of Disuse; Amputation of Tibia. (Schuchardt.)

To the peculiar conical shape assumed by most stumps Verneuil first gave the name "physiological conicity," describing it as occurring especially in arm and leg stumps, less often in thigh and forearm stumps, ascribing the latter to the lesser activity of cartilages of the upper ends of the radius and ulna. Numerous other writers have considered the same condition. Thus, in one of Liston's cases the humerus projected in extreme degree and terminated in a hooklike process or exostosis. Powers reported in 1890 a number of similar instances. (See Fig. 147.)

But the greatest student of the whole subject was Ollier, who gave great consideration to it in his treatise on "Regeneration of Bone"; for instance, long chapters upon the influences of irritation on the removal of various parts of bone; on their growth, in which he showed that the most common cause of hypertrophy of bone is irritation, and that the destruction of tissue and failure in its evolution have much to do with defective development and atrophy. He showed also that the essential factor in many cases of bony arrest was an indifferent activity, or a cessation of activity, in the epiphyseal cartilage cells. He showed that mutilation of bone nearly always tended to produce arrest of development, depending much upon whether the epiphysis or the shaft have been the more interfered with; furthermore, that in the forearm and in the leg the companion bone frequently undergoes alterations, sometimes in the direction of a compensatory hypertrophy, sometimes the reverse.

The most pronounced instance of such alteration ever noted by the writer was in the case of a sixteen-year-old girl with congenital clubfoot, who had for years walked entirely on the outer side of the same. In consequence of the malposition the tibia did not grow as rapidly as it should, while the fibula not only grew too fast but was apparently dragged upon by the traction of the displaced outer border of the foot. At all events, as the result of the combined deformity and disturbed stress the fibula was some three inches longer than the tibia and its lower end curved inward to just ninety degrees of a bony circle, while upon its outer border almost all the pressure of the limb was borne.

Thus, too, it may happen, after resection of the radius and ulna at the elbow, that the humerus, though not touched, ceases to grow with the same rapidity as does that of the opposite side, while if the humerus alone have been attacked the scapula on one side of it and the radius and ulna on the other, may be all indirectly affected. These alterations are late manifestations, and occur by gradual transition during which the bones diminish in volume, but increase in length. It was to this important and unmistakable phenomenon that Ollier has given the distinctive name of "*atrophic elongation.*"

He found this elongation especially in stumps, and here he studied it carefully. He recognized the fact that the less mobile the stump the more marked the atrophy, and he laid great stress upon the effect of functional inertia, seeking to assign its correct position among the contributing causes for atrophic changes. By observation and by experiment he came to the conclusion that the function of the limb is a necessary stimulus to the growth of its skeleton, and that with suppression of function atrophy inevitably results.

A thesis by Collette, in 1872 (Thèse de Paris No. 182), advanced our knowledge of the subject, since in it the author called attention not only to the above facts, but to the increase of fatty tissue which often accompanies wasting of

other soft parts. He also showed that along with atrophy other curious freaks may occur. Thus, he reports a case of gonitis, with wasting of both upper and lower limbs on either side, with great increase of fatty tissue, notable enlargement of the rudimentary breast, and marked atrophy of the testicle upon the same side. This is now a common observation, and every surgeon of experience can recall many cases of amputation stumps which have apparently been overgrown with adipose tissue.

Ollier's studies brought many confirmations and new observations. Thus, Haab, in 1875, mentioned pathological elongation after fractures, ostitis, and arthritis, laying the principal blame upon the epiphyseal cartilages, assigning a secondary rôle to inertia and immobilization, and claiming that for sympathetic elongation of the femur, for instance, it is enough to have a sufficiently active and lasting irritation of the tibia. Failure of pressure upon joints is an important factor in this estimate, and Haab proposes to substitute for Ollier's expression "atrophic elongation" "elongation from lack of pressure," which simply showed a failure to comprehend the factors involved, and inability to appreciate their essential identity.

In 1875 Gutenbock attributed bone atrophy of an amputation stump to an irritative action, evidence of which he found in the presence of osteophytes or other tissue alterations, which he considered to be results of functional inactivity. Milne-Edwards published, in 1861, experiments showing that if we deprive birds, for instance, of food containing calcareous elements the volume of their bones diminishes, but their position does not vary. This is of importance because under no known circumstances do the bones of man change perceptibly in their actual position, no matter how their shape or cell arrangement may alter.

In 1880 De Clerville published a remarkable case of nearly total disappearance of the humerus, first broken at the age of eighteen and twice after that. Only the epiphyseal extremities were left, and these were represented by only small pieces. The patient died at the age of fifty-two, the muscles of the arm presenting a remarkable atrophy and fatty degeneration. Similar cases have been reported in the treatise of Béranger-Feraud. In 1882 Segond described a reduction in the calibre of the vessels of amputation stumps or curtailed limbs, independent of muscular atrophy, and, in his opinion, an important contributing factor.

The causes, then, which lead to atrophy of limbs may be perhaps thus rehearsed or classified:

A. Functional inertia,

B. Inequality or defect of nutritive supply,

C. Inflammation,

D. Something in the general condition,

E. Trophic nerve disturbance.

The best summary of conditions which contribute to these results and of their general etiology and characteristics will be found in a thesis by Mondan, published in 1882, entitled "Recherches Expérimentales et Cliniques sur les Atrophies des Membres." One of the most important aspects of the subject is that which pertains to the atrophic elongation of amputation stumps, especially in the young, being not only of clinical, but also of medico-legal, importance. The facts above summarized seem to indicate that it should be a part of clinical teaching everywhere that any amputation made through the shaft of a long bone in the young and adolescent is very likely to be subsequently complicated by atrophic elongation of the bone itself, to an extent permitting it to first present and later perhaps actually protrude through that part of the stump composed of the softer tissue, thus causing it at least to assume a conical appearance, and sometimes to necessitate reamputation. In other words, *conical stump* is, at least in many instances, an inevitable consequence of developmental tendencies and nutritional conditions and is not to be blamed to the surgeon. While this knowledge should never excuse the formation of too short flaps in the performance of the amputation it will account for the actual occurrence in instances where they are made apparently of fully proper length, and will indicate, furthermore, the wisdom of making them extra long, especially in children. However, I believe it good practice, when making these operations upon the young, to forestall possible criticism by impressing the possibility of further bone-lengthening at some time in the vague future, should atrophic elongation produce this undesirable result. It ought, moreover, to be maintained that this is a natural process and that no surgeon can be held liable for damages for its occurrence, nor even open to criticism.*

It has been gradually demonstrated to the profession that the internal structure of the bones is not accidental nor lawless, but that the interior of every bone is built up, as it were, upon architectural principles, by which its strength and other purposes are more definitely effected. The changes which may be brought about by malnutrition, by atrophic nerve influences, or by disease may have, therefore, upon it the effect which undermining or "weathering" may have upon architectural structures. While many others led up to the more careful results later achieved, Julius Wolff has perhaps excelled in formulating both in diagram and in words the statics of bone architecture and the so-called laws of its development. Nowhere are these more beautifully apparent than in the general structure of the skull, and in the internal arrangement of the upper end of the femur, in both of which places appear, *in excelsis*, those lines of structure which make for strength and economy of material, and which permit the most perfect accomplishment of the former with the minimum of the latter. (See Plates XX, XXI, and XXII.)

* For more complete study of this condition see paper by the author, "A Study of Atrophy," in the Transactions of the American Orthopedic Association, vol. iv., 1891, p. 95.

It is, perhaps, changes of internal structure and pathological conditions which have most interest for the surgeon; such, for instance, as badly healed fractures, rachitic curvatures, ankyloses, angular deformities, where the more spongy texture especially seems to be most easily influenced by direction of pressure. The capacity manifested by bone, however, of adapting itself to various needs and changes would sometimes indicate almost a certain degree of osseous intelligence, and it has been part of Wolff's service to make plain and insist that every minute particle of bone is, as it were, prepared at any moment, to disappear or migrate just so soon as by change of internal conditions it has become statically superfluous, while, on the other hand, at any moment where at some particular point new bone is needed, it seems promptly there to appear in response to static demand. Moreover, this seems also to be true in general with regard to static needs, without reference to what may be required in a protective or prophylactic way, for the purpose of walling off or imprisoning foci of disease, although it must be said that the two purposes cannot be completely dissociated. It needs to be impressed, however, that under somewhat similar demands in other tissues bone may act in a similar way, and that most perfect pictures of multiple processes may be seen in bone where, softened or completely disintegrated by disease at one point, the consequent weakness is atoned for by a wall or shell of sclerosed bone serving apparently the double purpose above mentioned. Here too, the similarities of behavior between bone and lung are beautifully illustrated; for, just as we see pulmonary caverns lined with dense walls, and just as we see breaking down lung covered by enormously thickened pleura, so do we see in bones periosteum reduplicated to the same extent, and honeycombed bone which yet is *in toto* as strong as the original arrangement.

Too much can hardly be said to make impressive the results of either gradual or rather abrupt pressure upon the shape of a given bone area, or upon the growth of an entire bone. Thus, the ease with which the earlier forms of knock-knee or bow-leg may be straightened by simply raising the inner or outer border of the shoe, causing a slightly different implantation of the foot as a growing child learns to walk, will illustrate what an intermittent influence in this direction may accomplish. On the other hand, nothing more forcibly demonstrates the more or less rapid process of bone atrophy by actual absorption, with complete disappearance of bone material, than the encroachment made by a gradually growing aneurism or other tumor pressing, for example, upon the chest wall or the spinal column. Here, though there is apparently no other influence but pressure, the effect is pronounced and unavoidable, taking place quietly but without interruption, and causing large bone masses to disappear completely.

Some twenty years ago Charpy called attention to a practical classification of the bones of the skeleton under normal and pathological con-

ditions, which has an actual practical bearing (*Revue de Chirurgie*, September, 1884).

He would divide bones into three classes, as follows:

> *Red bones*, more vascular;
> *Yellow bones*, more fatty, both to the eye and to the finger; and
> *White bones*, which are drier, less vascular, more eburnated, and which are found especially in consumptives.

A given specimen may be difficult of assignment, but in general these distinctions obtain. All red or white bones are sure to become yellow during the old age of the individual, while in anæmic and albuminuric as well as some other patients these distinctions may all be lost.

Red or *vascular bones* are usually young or feeble bones, the latter containing a deep-tinted marrow, not deeply impregnated either with fat or with blood. Red bone, when fresh, "sweats" blood as the others do greasy matter, but when dry turns to a dark color. Such bones, when of powerful construction, with well-marked surfaces, and well supplied with vascular canals, are but slightly predisposed to tuberculous disease, in this respect resembling other richly vascular organs. It is of interest in this connection, and as bearing on the more recent introduction of the congestion treatment of Bier, to recall that Rindfleisch even in his day believed that in order to cure tuberculosis it was only necessary to create a hyperæmia. This would also explain the greater relative frequency of lesions in the hands and feet, which are possibly due to their distance from the circulatory centre. Moreover, the epiphyseal junctions are the least vascular parts of the bones, and are the most frequent sites of tuberculous disease. When the latter does occur it is usually at a time when the osteogenetic process is drawing to a close.

Yellow or *fatty bones*. Inasmuch as all marrow begins as red marrow, with one to two per cent of fat, and ends by becoming yellow, with from sixty to seventy per cent of fat, whether this change shall take place slowly or rapidly depends on diverse conditions, especially on that which is known as fatty degeneration. This condition is rarely perfectly established until, say, the thirtieth year, but the tendency to deposit is known to lessen in proportion, according to growth, as puberty is delayed. In adolescence we see the marrow of the large, hollow bones turning orange or brownish color, while in the hands and feet and scarcely united epiphyses (trochanters) it is manifestly fatty, these variations undoubtedly bearing some relation to the more sluggish character of the blood current through the bones. In fact, Bourgery believed that stagnation of blood current due to the cavernous arrangement of the bone favors the deposition of fat. Deposit seems to progress from the periphery to the centre, and the extremities undergo the change before the truncal portions of the skeleton. Thus, the pelvis, ribs, and vertebræ remain red bones much longer than the

others, and he whose sternum has become a really yellow bone must have reached a ripe old age. Even the distal extremity of the long bone will become fatty first, while one may see the greasy epiphyseal spot diffuse itself, as it were, across the remnants of the old, cartilaginous junction, and extend into the bordering bony territory toward the fat already contained in the marrow cavity, those regions nourished by the largest vessels the longest resisting the changes.

This fatty change varies in rate and date. Thus, the femoral neck may be friable and fatty at the fortieth year (an anticipated local senility) or firm, rigid, and still red at the eightieth. The bearing of these facts upon the general subject of fractures, especially in this region, will be obvious, but not germane to the present discussion. Long ago, in reviewing Charpy's work, I called attention to the possible occurrence of artificial anæmia caused by the Esmarch bandage, and asked the query how often, under these circumstances, in fatty and softened bone, the pale appearance of arrested circulation had been ascribed to inflammatory infiltration (*Annals of Surgery*, 1885, Vol. VIII., p. 469). I spoke there also of the care required in describing such morbid changes and of the fact that the exposure of a fresh section to air might very quickly and materially affect its tint.

The fatty condition above described is not to be confounded with a true rarefying ostitis, the effect of age or of other disease. The conditions, though often associated, are by no means identical. Adult fatty bone is not necessarily rarefied; its constituents are normally preserved, it is firm and solid, and its tenacity perhaps augmented. On the other hand, senile bone is essentially weakened in every respect. When the two conditions are combined they have been spoken of by some authors as *osteoporosis adiposa*, but that they are not differing manifestations of the same cause is shown by the fact that in old persons the sternum and ribs are rarefied and fragile, while their marrow substance is yet red. The condition called by some senile osteomalacia seems in effect to be this same condition of affairs, since the marrow of the truncal skeleton is brownish, not yet yellow, incompletely fatty, while the bones have been undergoing more or less rarefying atrophy. It is so with bone in immobilized limbs. It passes simultaneously into the double condition of adiposity and rarefaction, and is to all intents and purposes senile bone which has become such within a short time. *Its weeks have been its years.*

This deposit of fat is essentially due to diminished nutrition. The bone involved preserves its investments while, within, its finer spaces fill up with fat and its blood-vessels diminish in size. This process may be unduly hastened by alcoholism, by general obesity, or by immobilization, even that of ankylosis. The whole process indicates vitality diminished but not destroyed, since bones thus affected heal kindly and perfectly consolidate after fractures; and so too may be explained the fatty surroundings often noted about the tuberculous

focus. Ollier has found that after the extirpation of this focus the bones take a proper share in the process of repair.

Just as red bone seems too highly vascular to favor the growth of tubercle, yellow bone, on the other hand, seems too slightly so, and consequently affords no better soil. This is shown by young subjects, for example, in whom it is not rare to see tuberculosis arise in the centre of an epiphysis, yet very slowly invade the joint. This is not the case in adults, where the fatty epiphysis is slow to succumb and in whom much less of the joint end usually has to be removed or resected. This general subject has been long before the profession, yet has been generally neglected. In 1848 Nélaton wrote: "The spongy tissue of bones in adults presents two very different varieties, which may be designated as the adipose and the vascular or red. The ends of the long bones, and the short bones of the extremities, are constituted of the first, while the bones of the trunk are composed of the second. It is in this second variety of bony tissue, in adults, that tuberculous products almost exclusively develop. In young children these differences do not exist to any marked extent, the bones of the limbs, like those of the trunk, being formed of the red variety, and tuberculosis attacks either indiscriminately, but in the adult it is most often noted in the trunk. To this latter there are few exceptions, and the explanation of this is found in a tardy transformation of one variety into the other."

White or *consumptive bone* is, *par excellence*, favorable for tuberculous disease. The skeletons of tuberculous subjects have always been the favorites with men who make a business of preparing them, because of their whiteness and fineness of grain and minimum content of blood and fat. Their size and volume are proportionately less, and their surface markings not well developed. Even in adult age they are the bones of youth. For example, a humerus of the same length would weigh, in a very muscular subject 240 grams, in one moderately muscular 218 grams, and in a consumptive 167 grams; but in volume they do not so vary, while the white bone will astonish by its weight and density, even by its compactness. Those who have opened many consumptives' chests, in making autopsies, will recall with what difficulty the ribs are often divided.

The total growth of an organism is composed of that in the vertical direction (length) and that in the transverse (breadth and thickness). This is a truism which would not require emphasis here were it not that the two components have not exactly the same origin, since in bone the former is cartilaginous and the latter periosteal, and they do not always harmonize with each other. In infancy growth is mostly transverse, in adolescence vertical, finally returning to the infantile type. Occasionally in the adult we see one apparently predominating at the expense of the other. In the adolescent, vertical type, with slender bones developing in length at the expense of thickness, we may regard the condition as one expression of atrophic elongation, having its most common representation in the so-called "scrofulous individual," with long neck and

limbs, chest with reduced diameters, small waist and contracted pelvis, all of which is susceptible of interpretation to the following effect: We may regard bone as a definite quantity in the life of the individual, the blood being the dispenser of subsistence. According to the manner in which the blood is allowed to perform its function the skeleton will be well or ill proportioned. Hereditary influence aside, a youth grows tall because his transverse growth is feeble, and the latter is feeble because periosteal activity is in accord with that of the muscles; but a youth on whom is imposed more of the latter becomes large and strong, with well-developed muscles, at the expense of at least some of his vertical growth. When he has become an adult, cartilaginous growth slackens, periosteal growth becomes more pronounced, and his bones are more thoroughly vascularized. In other words, muscular activity of tall individuals and those of phthisical habit cannot do otherwise than reduce periosteal activity.

In a minor but equally significant way the same holds good regarding the growth of stumps and of immobilized limbs.

It is in such atrophic bone that the germs of tuberculosis make themselves perfectly at home, not so much as parasites, but rather as proprietors of the soil. Generations of their predecessors have prepared it, either directly or by circulatory inactivity, and handed it down by habit. It is poor soil, badly fertilized, insufficiently irrigated and drained, but it furnishes a suitable home for these germs, which settle by preference in just such localities as have been described, where they become tenacious and persistent proprietors. In spite of the gravity of such bone lesions, which we may paradoxically term *tuberculosis of the tuberculous*, they are fortunately not entirely beyond our resources. These statements pertain perhaps less to this chapter than to another, but are so germane to the subject that it has been difficult to avoid making them. They are, in large measure, a reproduction and condensation of those made by the writer in the *Annals of Surgery* for 1885, Vol. I., p. 466.

This being a chapter neither on teratology nor on deformities, I shall speak here but little of the *purely congenital affections* of bones, and of these only incidentally and under various headings.

Hypertrophy of Bone.

There are next to be considered two or three forms of *bone hypertrophy*, of varying origin, innocent in every respect save as they produce asymmetry, with compensatory changes in other parts of the skeleton, and perhaps even of the bone coverings. For example, one sees quite frequently a certain *inequality of growth of the lower extremities*, which rarely amounts to more than one inch, sometimes to much less, but which leads to an oblique position of the pelvis, with compensatory scoliotic curvature, and perhaps asymmetry of development of the face and of the thorax. It is obviously a serious mistake to treat such

a case with a jacket or to give primary attention to the spine. The most necessary feature of treatment is to put underneath the foot of the short limb a sufficiently thick artificial support or sole, in order to restore the pelvis to its proper horizontal position when the individual stands, and thus take away the actual cause of all the other changes. Such facts as these lead to the general direction that in every instance of scoliosis—and this is more particularly true of the milder types—the limbs should be carefully measured and the equality or the inequality of their growth determined. This is without reference to whether the cause is purely developmental or whether the condition is a sequel of some local bone affection or general toxæmia, such as may follow typhoid.

Another type of bone hypertrophy is the *compensatory and physiological overgrowth of one bone in order to meet demands made upon it because of weakness or loss of its companion bone.* This is seen most conspicuously in the leg, and particularly when the tibia has been essentially weakened or has been destroyed or removed. In these instances the fibula undergoes a relatively enormous and disproportionate enlargement, thickening and strengthening in every direction and feature, so that in time it becomes quite able to assume the full duty which normally falls upon both leg bones in supporting the weight of the body. Similar results, but perhaps less conspicuous, are seen in the forearm.

Another expression of compensatory hypertrophy is seen after the loss of one limb and the relatively abnormal development of the other. This is true alike of its bony structure and of its muscular and other soft tissues. While this is going on in the remaining limb, the stump, on the supposition that the loss was effected by an amputation, undergoes a corresponding atrophy, with elongation of the bone shaft, elsewhere alluded to in this chapter as *atrophic elongation.* In such an instance, then, we see beautiful illustrations of two physiological processes of opposite types proceeding side by side.

Yet another type of usually localized, yet possibly generalized, hypertrophic bone changes is met with as an expression of irritation and overgrowth due to the presence of some irritating material, supposed to be a toxin circulating within the fluids of the body. Reference is intended here more especially to the peculiar changes which are known sometimes to follow *typhoid*, either in its exceedingly acute forms or perhaps more commonly in the rather milder types of disease, where young people seem to grow at a relatively much faster rate during or more commonly after convalescence. While this is true, especially of typhoid, certain of the other continued and contagious fevers are more rarely the apparent causes of similar changes. Pathologists and surgeons seem inclined to regard these as an expression of extra activity along epiphyseal junctions and to consider the circulating poison as the irritant which provokes it. This pertains, however, not alone to the long bones of the limbs, but even the spine and perhaps the pelvis seem to participate. This explanation is certainly vague, but is probably as accurate as it can at present be made; or one

may perhaps sum it up to this effect, that in both the bone marrow and the juxta-epiphyseal regions nutritional activity and consequent growth are more pronounced than normal, or than they previously had been in the individuals affected, in consequence of which the skeleton seems to undergo relatively an unusually rapid development.

A sharp distinction must be made here between the acute ostitis and osteomyelitis which so often follow typhoid and the other fevers, or even dysentery, cholera, and smallpox, and the rapid growth just described. The question of bones succumbing to acute infectious processes is quite another one, and does not belong within this chapter, nor perhaps do the so-called "growing pains" of youth, although these are more likely to be of the non-infectious, innocent, and irritative character than of the infectious or truly inflammatory.

The bony changes which were formerly supposed to be so frequent after *rheumatism* are now to be placed under a different heading; at least, this is true of most of them, since we have learned that that which used to be called rheumatism of bone is rarely such, but is either of syphilitic or tuberculous, or, at any rate, of some other character. It is possible to have a rheumatic affection of the periosteum, but whether the true osseous structure can ever be regarded as subject to actual rheumatism is exceedingly questionable and, in the writer's estimation, is not to be thought of. The term "rheumatism" should not be used as one under which to group all sorts of conditions for which we have no other known excuse or etiology, and, so far as the bones are concerned, most of what used to be called rheumatism is something quite different. Nevertheless, it must be acknowledged that, in connection with true rheumatism involving the white fibrous structure of the periosteum, there may be thickening and subsequent ossification, which may produce more or less noticeable changes in the shape and perhaps even the function of certain bones. The sooner, then, the term "rheumatoid ostitis" is expunged the better, because we do not know what rheumatism is, and the term is altogether too uncertain and unsatisfactory. *Least of all should any truly inflammatory or suppurative lesion be connected with the expression rheumatic*, since the two conditions are about as far apart as is possible. Inaccuracy of expression from lack of knowledge has in time past led to serious blending and confusion of the expression "rheumatic" with numerous lesions, most of which later turn out to be tuberculous, or bone abscesses of osteomyelitic origin and exceedingly slow course, and most of the conditions termed rheumatic are nothing of the kind. Let us, therefore, if possible, in future entirely dispense with any connection of the two terms "rheumatic" or "rheumatoid" with bones and their diseases.

Gigantism.—There is, however, one form of congenital hypertrophy which may occasionally call for surgical intervention, and that is the so-called *gigantism*, having reference especially to those forms of disproportionate overgrowth of limited portions of the osseous skeleton, along with their overlying soft tissues,

which may cause but slight variations from the normal, or sometimes most pronounced and bizarre illustrations of perverted and diverted nutrition. Such instances are seen most often in the overgrowth of one or two fingers or toes, causing the part involved, in early childhood, to assume proportions of the adult, or even more pronounced than these. When an entire limb is involved its relative proportions may not be materially distorted, but, as compared with the rest of the individual's body, it is literally gigantic in size; or if both lower limbs be developed to a far greater extent than the proportions of the rest of the body would justify, the same term applies. Instances of this kind have been exhibited as museum freaks, and in my text-book on surgery I have illustrated the peculiarities of the case of a young woman who exhibited herself for some time, whose feet and legs were developed to simply enormous proportions.

Some of these cases seem to be of congenital origin. In others, changes are not recognized in infancy or early childhood. In some of them an apparently hereditary influence can be traced; in others no explanation is afforded. The condition is free from pain or symptoms of any kind save those produced by inconvenience and undue size. If any explanation can be afforded it must be ascribed to perverted trophic influences through a limited tract of the nervous system, else the condition would be general and not local.

In some instances, as when fingers or toes or even a part of the hands and feet are involved, excision or amputation may be considered an improvement on the existing condition, and, in such a case, will be not only justifiable but indicated; otherwise little or nothing can be done. To cut off the main blood supply of an entire limb in order thus to regulate its growth is at best a hazardous expedient, since the effect may be easily overdone and gangrene might be the consequence. Wearing of an elastic bandage of a proper degree of tightness will probably be the most promising measure of non-operative character.

Acromegaly.

The term acromegaly is now made to include a disease of trophic and more or less degenerative character, whose most conspicuous features, however, pertain to the osseous system, and which perhaps deserves consideration in this place rather than in any other chapter in a work of this character. Were it not for the enlargement of the bones, the other changes accompanying it would be far less conspicuous. It has passed under other names and has been described by writers under the terms Pachyakrie, Hyperostosis, Prosopectasis, and Gigantism or Giant Growth. Its identity as a distinct type of abnormal growth was first demonstrated by Marie, in Charcot's clinic, in 1886. Its most characteristic features are enlargement or thickening of the apices and extremities of the skeleton, *i.e.*, the fingers, the toes, the chin, the nose, the jaw, and gradually many or all of the other bones; while, at the same time, the softer

tissues having special shape or purpose, such as the ears, lips, cheeks, the tongue, and sometimes even the penis and the clitoris, show a similar tendency to overgrowth. (Figs. 148 and 149.) The disease is to be distinguished from elephantiasis, as well as from myxœdema, in which the softer tissues are involved. The osseous changes constitute a true pathological hypertrophy, beginning at the extremities of the bones involved, save that the bones of the face and cranium are often the site of a more diffuse form of hyperostosis, which by itself might be considered a leontiasis.

No matter whether hereditary influence prevail or not, the first evidences of the disease appear usually during youth or early middle age. Its course is long and tedious throughout, and is accompanied by many nerve disturbances of varying grades, including those of sensation, "rheumatoid" pains in the limbs, clumsiness and loss of control of the hands, general weakness, and inco-ordination with emaciation. In most instances there is more or less complete loss of sexual desire and power. There appear in the face peculiar changes of physiognomy, most conspicuous in the lower jaw and the supraorbital ridges. Simultaneously the hands and feet begin to enlarge, and in the course of a few months there is a marked disproportion in size between these parts and the rest of the body. The disease runs a course usually of from three to five years, and may then remain for a time stationary; in exceedingly rare instances some later improvement has been noted. Its tendency is toward a fatal result in from ten to thirty years, the last stages being characterized by well-marked atrophy of the skin and muscles and a rather peculiar cachexia. Death is finally caused through involvement of the heart and vessels.

Fig. 148.—Acromegaly. (Case from author's collection.)

A more minute description of the most pronounced trophic changes would include over-development of the fingers and hands, so that the former become almost sausage-like, their length being increased as well as their other dimensions, the nails expanding to correspond. Similar changes occur in the feet, which become abnormally plump and heavy, the length of the sole much in-

creasing and the toes behaving as do the fingers, especially the great toe, which enlarges more rapidly than the others. The legs and the forearms thicken, much as in elephantiasis. The face becomes elongated in an oval direction, and the lower jaw protrudes almost formidably. The lips and tongue thicken and enlarge to correspond, even to such an extent that the mouth is kept habitually opened, and speech is affected. The eyelids become tinted an olive brown, as well as enlarged and thickened, and the nose becomes much flattened. Not infrequently the teeth loosen and drop out. Similar but less conspicuous changes occur in the vertebral column, which becomes often kyphotic or twisted into a scoliotic curve. In the ribs and sternum overgrowth also is manifested, and the latter is usually pushed forward. Even the larynx is often increased in size, with a corresponding deepening of the voice, which in women becomes masculine. With the other alterations and features we are in this place less concerned. (Figs. 148 and 149.)

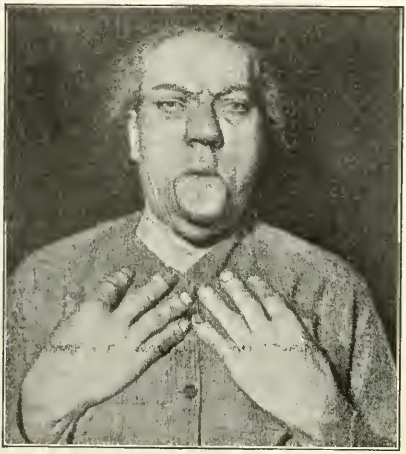


Fig. 149.—Acromegaly (woman of forty-eight). From Krause. (Schuchardt.) Face and hands particularly affected.

Regarding the etiology of the abnormality we have at least gotten to a point where attention may be called to variations in the thyroid, the thymus, and the hypophysis, *i.e.*, the pituitary body, one or all of these parts being found involved in every instance which is carefully studied. Exactly in what their abnormal relations consist, however, is still a mystery. With the other changes in the cranial bones there occurs a widening and deepening of the sella turcica, in which the pituitary is accommodated, and the latter is often increased to two or three times its normal proportions. While one may clearly appreciate these alterations it is difficult to figure out as yet exactly wherein lies the primary cause of the nutritional disturbances. These pituitary changes are by no means invariable, and instances occur in which it seems but slightly affected. In proportion as the disease assumes these relatively enormous dimensions, disturbances of vision occur, and there is not only pressure upon the optic nerves, but exophthalmus may even be noted.

It must suffice here to call attention to the resemblances as well as the differences between acromegaly and gigantism, which nevertheless may be associated in the same case, or which may closely resemble each other in some

extremely significant ways. It is impossible to avoid the conclusion that etiologically they are closely related, while clinically one lacks some of the characteristic features of the other. Throughout the whole consideration of these nutritional changes in bone we are constantly confronted by those unsolved problems already alluded to, which deal with the mysterious relations obtaining between the genital glands, the thyroid, the thymus, the pituitary, and perhaps some of the lymphoid structures of the body, and nutrition changes or abnormalities. This topic might form the subject for a long essay, but this, no matter how much information it might furnish of that which is available, would still leave the question unsettled.

It is questionable if any treatment for acromegaly may be made really effective. Yet, if such a case be seen early it would be well worth while to experiment with the various extracts, thyroid, ovarian, etc., since through a well-directed opotherapy one is perhaps more likely to reach the central cause than by any other means.

Limited or Circumscribed Hypertrophy of Bones; Osseous Elephantiasis.

Aside from the *leontiasis* which, in name at least, is a matter of overgrowth of the facial bones, especially the jaw, we may have somewhat similar limited or circumscribed hypertrophies of other parts of the bony skeleton, which are yet to be distinguished from gigantism, where growth seems to be symmetrical, though more or less limited, and from acromegaly, above described. While some of these changes are compensatory, some are regenerative, and yet others are the result of previous inflammatory processes. Many of them may be explained on the theory of a periostitis ossificans. It is hard to distinguish some of them again from the so-called *periosteal* or *external osteophytes*, which may be developmental in origin, or may have some other cause. Moreover, there occur sclerosing and tumor-forming processes in the interior of long bones, which give rise to the so-called *endosteal* formations or *internal osteophytes*, which have also to be distinguished from the conditions just mentioned.

Such lesions, for instance, as those portrayed in the accompanying illustrations may be the result at different times of different pathological causes, yet in the finally prepared skeleton may all appear much alike. The particular instances here pictured are taken from Volkmann and were denominated by him "elephantiasis of bone." (Figs. 150 and 151.)

Something similar may be the result of hemorrhages occurring beneath the periosteum, or between the bone and the endocranium, the blood-clot not finally disappearing, at least not completely, but being gradually changed into more or less hard bone, with the production of that which would be ordinarily called an *osteophyte*.

The intent here is to call attention rather to those lesions which have an absolutely non-inflammatory origin than to speak of the end results of the infectious processes which are well known to be often sclerosing, or the slow consequences of syphilitic changes in bone which are dealt with in another article.

FIG. 150.—Dense and Extreme Osteosclerosis ("Elephantiasis Ossium") following Chronic Ulceration of Leg. (von Volkmann.)

Exostoses and *osteophytes*, in general, may perhaps as well be considered here as elsewhere. They are quite worthy to be included, at least in one way, under the classification of tumors, in that they are new growths and that they have no physiological function. Yet they vary, in number and in general clinical course and appearance, from the so-called true osteomata, and deserve consideration by themselves.

To the quite irregular and extremely variable outgrowths which occur in various parts of the skeleton, but which spring most often from the more spongy portions, and rather from the extremities than the shafts of long bones, is given the term *osteophyte*, implying thereby the lawless and irregular, at the same time usually harmless, character of the growth, and also its multiple features.

FIG. 151.—Large Shield-shaped Exostosis Beneath a Chronic Ulcer of the Leg. (von Volkmann.)

Such outgrowths, occurring in multiple form, as are frequently seen along the vertebral column of elderly people, sometimes are to be included among the conditions to which the expression "ostitis deformans" is applied, though sometimes they occur without any explanation. While, therefore, they may be a feature of a deforming ostitis they are not necessarily so, and unless overdeveloped or growing in some peculiar location where their existence gives rise to pressure symptoms, they are quite compatible with good health. Not infrequently, however, they cluster around the intervertebral joints in such a way as to produce limitation of motion, this being one cause of the rigidity of the spine so often seen in elderly patients. Those outgrowths, to which ordinarily we give the

term osteophytes, are, in other words, seen more commonly about the spine and the cranium than elsewhere. To entitle them to the designation, they should arise with the mildest of any cause. They are to be distinguished from another form of osteophytic growths which are a feature of irregular and abnormal ossification of exuberant callus, and which have, therefore, to do with pathological sequels of fracture. The true osteophyte is distinguished especially in this, that it has rarely traumatic or other known cause.

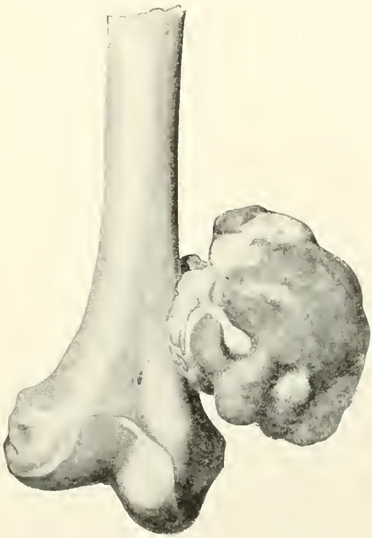


Fig. 152.—Cartilaginous Exostosis (Exostosis Bursata) at the Lower Part of the Femur. (Lexer: "Lehrbuch der Allgemeinen Chirurgie," 1905.)

Exostoses, on the other hand, are rarely multiple and have in the main this distinguishing feature, that they do not involve the entire thickness of the bone from which they spring, but are rather distinct outgrowths, often connected only by a small bony pedicle. They are prone to develop in those locations where in the lower animals there has been some bony process which has disappeared in man, as, for instance, the supracondyloid process at the lower end of both the humerus and the femur, especially the latter. Here such a growth may be regarded as in some respects *ataristic*. While perfectly innocent in their structure and tendencies they are nevertheless sometimes troublesome by accident of their location or size. This is especially true of the exostosis which not infrequently appears just above the inner condyle of the femur, or sometimes on the outer side, which grows slowly, constitutes a prominence which is quite distinct from the normal bone, and over and around which, in time, there is formed by perfectly natural processes a thickened bursal sac, which may contain quite a little quantity of fluid; the whole constituting that which is described, especially in Continental literature, as *exostosis bursata* (Fig. 152). Every feature of this condition is innocent, and yet it may assume a size which causes it to be troublesome and perhaps, to some extent, disabling. The bursal sac is usually distinct from the synovial cavity of the joint, but may possibly communicate with it. The surrounding structures are displaced, and in time perhaps the play of muscles, or even of the joint itself, is hindered.

The *treatment* of exostosis bursata is of the simplest and most successful de-

scription. Through a suitably planned incision the growth may be easily exposed, after which its relatively small connection with the femur should be severed with chisel or forceps and the entire spongy, bony mass dissected out, with its overlying bursa.

Leontiasis.

Leontiasis is the name given to a condition first described by Virchow, having origin usually in youth and confined mainly to the bones of the face and cranium. In course it is very slow, and in outlook absolutely hopeless. It consists of a painless proliferation of bone, going on irregularly and simultaneously, involving nearly all of the bones of the head. In consequence they become relatively enormously thickened, which gives to the head that peculiar appearance which has caused it to receive the descriptive name leontiasis. (Fig. 153.) I have just stated that the growth is painless. This is true until the bones have assumed a thickness which causes pressure to be made on sensory nerves, or until the capacity of the cranium is so reduced that one begins to see evidences of increased brain tension. Though the growth is in itself innocent, the last months of the patient's life may be accompanied by intense suffering, or by paralysis of the special senses. The cause of the changes is absolutely unknown. In some instances there have been previous attacks of erysipelas or of suppuration of the lachrymal passages, and yet no direct connection can be traced. One may sum up our present knowledge on the subject, then, by simply confessing that absolutely nothing is known regarding its etiology.

Fig. 153.—Leontiasis Ossea. (von Volkmann.)

So far as its treatment is concerned we are also helpless. When such an extent of the cranium is involved as we see in most instances there is no possibility either of resection or of any other operation which will permit of any benefit to the patient.

Rachitis: Rickets.

In general, rickets constitutes a disease to be spoken of as among the constitutional and general nutritional, whose most pronounced expressions are seen in the bony skeleton. While essentially diathetic and often spoken of as a starvation disease, it is consequently most looked for among the children of the very poor. It is a starvation matter, however, only in that the bones of the

growing fœtus or infant are starved, since they do not secure a proper amount of nourishment, this having to do more with the financial means or social environment of their parents than with physical conditions, and being solely a question of suitable nutritional supply for the needs of a growing fœtus. Some of the most pronounced cases of rickets are seen among the children of the well-to-do, whose mothers, however, have either been deficient in the quality of the milk with which they have nursed their children, or of the blood which they furnished them previous to their birth, or else who have been so devoted to social affairs as to have neglected their primary maternal duties, and have left the question of nourishment either to artificial foods or to living substitutes for themselves.

Under the general term rickets have, moreover, been included conditions leading to practically identical results, but perhaps arising from different sources, so that when considering the subject analytically we should separate those cases arising from prenatal conditions and those having a postnatal origin. In other words, an infant may be born with characteristics of what is known as *intra-uterine* rickets, including the various *chondro-dystrophies;* or an apparently healthy infant may, from lack of proper food, develop the essential features of the rickety condition, and more or less quickly fall into a general state indistinguishable from that produced in the aforementioned way. Again, a little later in life children who are half or more than half starved, and who are brought up, as are many of the children of the very poor, especially in large cities, amidst the worst of hygienic surroundings, gradually develop deformities which are only explainable on the occurrence of the same general changes which denote rickets in the instances already noticed. And, finally, there is a so-called adult or even senile type, which is perhaps not rickets in its proper sense, but should rather be considered as an expression of osteomalacia or senile atrophy of bone, usually free from expressions of at least acute or actual disease, but producing deformities of various types, sometimes of the atrophic, sometimes of the hypertrophic, form.

As between rickets and all that has been included under the term, and osteomalacia, it has not always been possible to make clear distinctions, desirable though it be to have them.

So far as the bio-pathology and pathological anatomy of rachitis are concerned the most conspicuous change is, of course, in the disappearance of those mineral elements which give the bone its rigid support, and which suffer a notable diminution. Normal proportions existing between the organic and the inorganic elements of bone are about thirty-five to sixty-five, whereas in typical rickety bones these figures are just about reversed, and the mineral elements sink to about thirty-five per cent or nearly one-half of the normal. Next to this change the most pronounced is an abnormal proliferation of the periosteum, as well as of the endosteum, with a substitution of richly cellular fibrous tissue for the

more typical bony elements, and the subsequent development therein of a very spongy osteoid tissue: these changes occurring especially in the epiphyseal regions and at those points where cartilage is being transformed into bone. Here there is an irregular, vascular, and fibrous invasion of the cartilage, and changes occur, especially along that zone where calcification should be taking place, so that cartilage itself assumes more and more the appearance of osteoid tissue, yet lacks its rigidity. The sharp differences which usually exist between the cartilage and the red marrow disappear, the whitish calcification line vanishes, and the entire region between cartilage and bone becomes far less distinct. Meantime externally the periosteum is proliferating with more or less formation of osteophytes. In brief, when section is made of bone thus involved, the normal picture is quite altered, and it seems to be a confused and commingled collection of all those elements which go to make up ordinary bone structure.

Regarding the nature of these changes, notions have been mainly divided between two extremes, some holding that the first change was the solution of the mineral elements and their absorption into the blood stream, the other changes being secondary. Others have held, on the contrary, that the primary change is the organic alteration of the bone tissue, the loss of calcium and magnesium salts serving to check rather than to make it more pronounced. Being concerned less with the minute nature of the disease than with its clinical and surgical expressions, we will refer the reader for further information in this direction to the large treatises on pathology, which concern themselves especially with questions of this character. At all events, be the origin what it may, significant indications of rachitis rarely appear before the fourth month after birth, so that, whether they have or have not an intra-uterine origin, one scarcely sees them until this date is reached. It is during the second year that they become most prominent and most often noticeable, while during the third year they are much less common.

Rickets is not a disease of any one race or climate. Nevertheless, it is much more frequent in some parts of the world than in others. For instance, it is relatively uncommon in Greece and Turkey, still more so in India, China, Japan, and Australia; while in northern Norway, Iceland, and Greenland, it is almost unknown. On the contrary, in southern Europe, even in its mountainous regions, and in Great Britain, as in the more crowded portions of the United States, it is quite prevalent, and may be looked for, not alone in the homes of the poor and ill-fed, but often in those of the well-to-do, for reasons already given. Inasmuch as cold weather tends to keep children indoors, its worst and most acute expressions are met oftener in winter than in summer. In this chapter we have to concern ourselves obviously only with those indications of rickets which pertain to the osseous system, and of these it may perhaps first be said that scarcely one, if any, bone in the body is exempt from its characteristic alterations. They may be topographically arranged as follows:

1. Alterations in *the head*, including so-called *cranio-tabes*, or softening of the cranial bones, especially those of the vertex, in spots, in such a way that perforations may follow the softened areas and the faulty cranium become fenestrated. Furthermore, we may have here widening of the fontanelles, thickening of the frontal and parietal prominences, as well as of the upper and lower jaws, marked irregularity in the eruption of the teeth, and quite significant alterations in the alveolar processes.

Fig. 154.—Fœtal Cretinism. (Bode, in *Virchow's Archiv*, Bd. 93.)

2. *In the chest* the phenomenon most frequently noted is the so-called rachitic rosary, produced by typical enlargement, *i.e.*, proliferation, of the costochondral junctions, and appearing most pronouncedly from the fourth to the eighth ribs. Beside this almost pathognomonic sign there are alterations in the dimensions and shape of the thorax, including prominence of the breast-bone, producing the so-called "pigeon breast," widening of the lower lateral diameter and intensification of the S-like curves of the clavicles. The *spinal column* suffers less often than do the ribs and breast-bone, but there may be produced very distinctive alterations of contour, causing spinal curvatures, that need to be distinguished etiologically from those caused by spondylitis or by a scoliosis from perverted function.

3. *The pelvis* is a frequent site for well-marked alterations in contour, and especially in dimensions, of the pelvic cavity, leading to changes which especially concern the obstetrician, since by some of them parturition is made at least difficult and sometimes quite impossible. Consequently the question of rickety pelvic bones is sometimes inseparable from that of the most severe obstetrical or gynæcological operations.

4. In the *upper extremity* is noted most often thickening of the epiphyses, which appears usually first at the lower end of the ulna and radius, but which may involve both ends of all three of the main arm bones.

5. The *lower extremities* furnish more pronounced illustrations because upon them rests the weight of the body so soon as rickety children begin to walk, and because this weight will naturally tend to produce curvatures or other de-

formities when bones called upon to support it are abnormally flexible. Here the earliest changes appear usually either at the lower end of the tibia or about the knee, and various degrees of *knock-knee*, *bow-leg*, and *flat-foot* betoken the type of the disease and may easily permit its immediate recognition. The relations of rickety softening to *coxa vara* are also more and more frequently noted. Extreme involvement of all four extremities may even compel young children to creep upon all fours instead of assuming a natural gait.

Sometimes these rachitic bones *fracture very easily*, in which case one may assume an early and more complete form of decalcification of the bones. On the other hand, after the early expressions of rickets have passed and the deformities alone remain, children having recovered from the diathetic condition, one is often astonished to see with what amount of force he must act in order to restore bones to their natural contour, and this is true whether he is attempting forcible redressment, *i.e.*, osteoclasis, or is making bone division and using the bone chisel. There seems in this way to be more than complete atonement for early calcareous losses, and bones now are unusually hard and dense which at one time were soft enough to bend easily.

Briefly summed up, then, we may say that in rachitic bone the actual condition is one of a thin cortex which still contains mineral matter, which is surrounded by a layer of so-called osteoid tissue, from which calcium salts have disappeared. This at least is the actual condition in many of these cases which permit of the so-called green-stick fracture. Here the concave wall of the shaft breaks, according to Rehn, because it is exposed to the greatest strain; the opposing side of the bone, being stretched until it reaches a point where it can no longer stand it, may finally yield. In these cases when callus forms it is produced at the point of actual fracture, that is, on the concave side, and may attain so great a strength that the angulation is corrected and the general contour of the bone improved. A complete fracture in rickets seems less common than green-stick. Here again the actual interrelations of these various conditions of bone are by no means standard nor everywhere considered even under the same caption. What one writer refers to under the name rickets another may include in his chapter on osteomalacia, all of which adds to the difficulty of accurate and scientific or analytical consideration of the subject.

If other *accompanying indications of rickets* are mentioned here it is only that diagnosis may be facilitated. Briefly and for this purpose it may be therefore stated that rickety children are usually more or less anæmic, and often suffer from failure of digestion and from constipation, with meteorism, or sometimes from intractable diarrhœa. Pulmonary catarrhs and inflammations frequently attack them, and they seem peculiarly susceptible to all sorts of intrathoracic diseases. So far as their nervous systems are concerned there is increased irritability, sometimes amounting almost to mania, which may include sleeplessness and restlessness, with cramps and occasional laryngismus, while,

especially in some parts of the world, tetany is frequently met with in these cases. The spleen is nearly always enlarged, the liver is frequently increased in size, by which the abdomen becomes abnormally large and prominent: the muscles are weak and atrophic, not infrequently subject to some spasmodic affection, yet, peculiarly, while other tissues fail to develop, there is usually abundance of fat. Vasomotor disturbances are especially indicated by the profuseness with which the subjects of this disease perspire, especially during sleep, about the head and forehead.

The peculiar spasms, especially of the respiratory apparatus, above alluded to (*i.e.*, laryngismus), cannot be dissociated from those so expressive of that general condition known as the *status lymphaticus*, and it deeply concerns the clinician to ascertain more and more fully the relations between these and rickets. This is all a part of that general difficulty of assigning a distinct, specific cause for each expression of defective nutrition or abnormal over-nutrition. I have elsewhere called attention to the possibility of recognition by the surgeon of the status lymphaticus when present (*Surgery, Gynæcology, and Obstetrics*, August, 1905, and in the *Transactions of the American Surgical Association* for 1905). I took occasion there to show that many rickety children had the so-called lymphatic diathesis so pronouncedly present as to make it necessary to be most cautious in the use of anæsthetics. I insert this here because of the still further relationship between the status lymphaticus and the enhanced dangers pertaining to the use of these drugs; all of which is fully set forth in the manner above mentioned. The complicated relationships are furthermore indicated in the fact that opotherapy is equally advantageous in both conditions, while the general hygienic measures, as well as drugs to be administered, are identical.

Differential diagnosis is, then, mainly to be made between osteomalacia, hereditary syphilis, tuberculosis, and incipient hydrocephalus. So far as osteomalacia is concerned there is no doubt but that cases of one type are regarded as belonging to the other, and there is no doubt again but that atrophic and rachitic changes may be so combined as to make some cases impossible of assignment. In general, however, rachitis is a disease of childhood, while the ordinary form of osteomalacia is rather one of adults. Abrupt distinctions cannot here be made.

So far as concerns hereditary syphilis there is no doubt but that many rachitic children are born of syphilitic and cachectic parents, especially mothers, but the actual relations between the two diseases are accidental rather than causative. While syphilis of the mother may account for malnutrition of the fœtus, there is no reason why two morbid processes may not go on simultaneously, each perhaps being tinctured by the other. From tuberculosis it is rarely necessary to differentiate rickets, save in accounting for certain spinal curvatures, and even here it should be rarely if ever difficult. Hydrocephalus may

also occur in rickety infants or children, without being necessarily attributable to this disease, but, in the first stages, when ossification is known to be slow and the sutures are ununited, while the skull is beginning to expand, then one may be still in doubt.

Concerning the various deformities attributable to rickets the reader must consult other portions of this work, for it is certainly unnecessary to reiterate

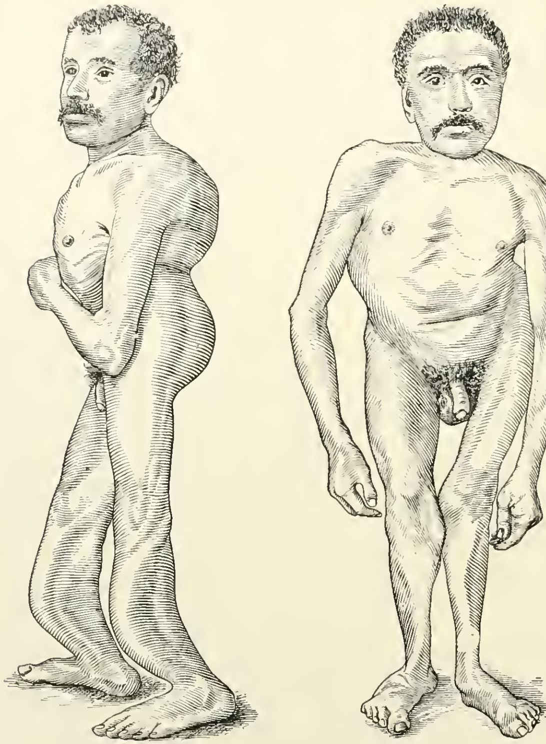


Fig. 155.—Extreme Rachitism. Case of Louis Guillot, aged 56, of Lyon, France. (Duplay et Reclus: "Traité de Chirurgie," Paris, 1890.)

here descriptions which need to be more fully given in other chapters. They have been sufficiently recounted by many, and it must here suffice to say that curvatures and affections of all of the bones, involving their size and shape, may be met with, and that there is scarcely any imaginable alteration which has not been noted. (Figs. and 156.) So far as they constitute orthopedic defects or deformities, they are amenable to mechanical and operative treatment, to a degree

which is now both surprising and gratifying. The introduction of the general principle of subcutaneous osteotomy, for instance, applicable in so many parts of the body, and in so many ways, has constituted a very distinct advance in orthopedic surgery, while the observance of an accurate aseptic technique has made it almost absolutely safe. *A combination, then, of operative treatment and external support* can be devised to meet the exigencies of nearly every case, certainly of every one taken at a reasonably early period. That museums are

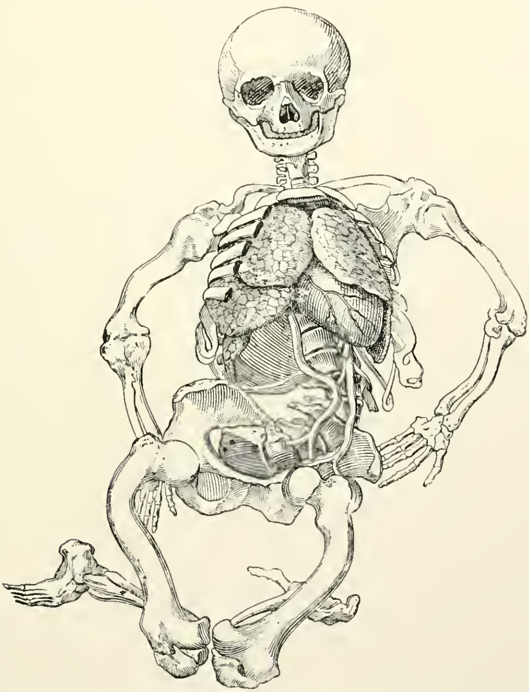


Fig. 156.—A Skeleton Completely Deformed by Rachitis. (Fort: "Pathologie et Clinique Chirurgicales," Paris, 1873.)

filled with examples of extreme distortions and deformities is an indication of ignorance in the past rather than of present limitations.

So far as the *general treatment of rickets* is concerned one must have regard to the general welfare of the patient, be he young or old, and must first concern himself with such an environment as to afford sunlight and fresh air in abundance, with food adapted to his special needs, made rich enough, especially in the calcium salts, and abundant enough to permit no lack in this direction. Yet

for children who suffer from chronic constipation or from obstinate diarrhœa it is not easy to arrange such a diet list. In the way of *drugs* one must make a judicious combination of opotherapy and the ordinary resources of the chemist; and such judicious selection will require a careful regard as well to whether we are considering the actual and active condition or its mere consequences. The anæmia is to be overcome, the lacking mineral elements are to be supplied, and, if we have any adequate knowledge of those mysterious primary causes whose interdependence has been disturbed, and whose general public expression is the rickety condition, we must not fail to take advantage of it. If, moreover, it be made to appear that all this can be best effected through a suitable opotherapy, then this must not be neglected. While there is still so much to learn specific directions cannot yet be given. But *no infant or young child should be treated for the active rachitic condition without at least an experimental trial of pituitary, thyroid, thymus, or one of the other animal extracts,* combined perhaps with bone marrow, while, at the same time, distinctly lacking elements may be supplied by an assimilable and palatable combination of such remedies as the hypophosphites or, better still, the glycerophosphates, unless the latter prove too stimulating, with phosphoric acid, with manganese, or with iron, the constant effort being to do enough in this direction, yet not to overdo.

The rapidity with which young rickety children can be built up and made to lose their irritability, their anæmia, and their dyscrasia, by keeping them in the open, feeding them proper food, and administering small doses of some of the above preparations, makes rickets, after all, and especially when taken early, a most satisfactory disease to treat, results being striking and gratifying in proportion as one has complete control and early assumption of responsibilities.

Osteomalacia; Osteopsathyrosis; Fragilitas Ossium; Osteoporosis; Halisteresis.

Under these various terms are included conditions whose final expression is one either of softening or of textural weakening, or both, with abnormal flexibility or fragility of bones. The condition may be brought about by more than one cause, although behind every possible case are the essential features of defective nutrition and disappearance of calcareous material, but the clinical result appears in either one of two forms, *i.e.*, such *softening* with consequent *flexibility* as to permit of *distortion* and *deformity*, or such actual *weakening* and *fragility* as to permit of *fractures with a minimum of violence*, even to a degree justifying the expression "*spontaneous*." Inasmuch as these terms are somewhat differently used by various authors it is not easy to give each an exact significance which shall be acceptable to all.

In most respects these conditions are all atrophic and retrograde, and in the

main they pertain to bones already fully developed; nevertheless, in bones which have not attained full development, atrophic disturbances take similar, but not identical, courses. Occasionally the disease has appeared in endemic form, and considerable areas of country have at various times been affected; as, for instance, Switzerland, Italy, and South Germany. *Osteomalacia of the adult* begins usually with a well-marked congestion of the marrow, and an extreme vascular disturbance which must be referred to vaso-motor influences. In other cases absolutely no satisfactory explanation is at hand.

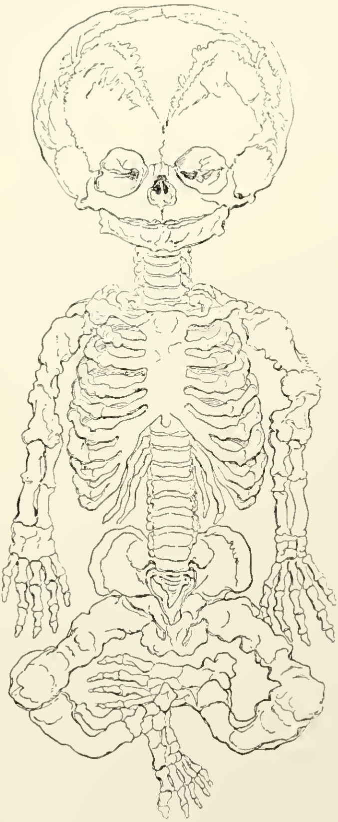


Fig. 157.—Congenital Osteomalacia. (von Volkmann.)

The expression *halisteresis* refers especially to decalcification of the bones, *i.e.*, where calcareous salts disappear by solution and absorption, leaving the bone actually softened and in consequence more penetrable. The marrow may now be subject to hemorrhages, and pigmentary deposits may mark their site, or cystic degenerations may replace the outpoured blood. Whether the affected bone shall be made flexible or fragile will depend not so much upon the disappearance of its mineral matter as upon exactly what happens to its other texture, *i.e.*, it is dependent upon the character of the atrophic and degenerative process.

Puerperal Osteomalacia.—There is a well-known *puerperal form,* which may begin early during pregnancy or perhaps not until its conclusion. It usually comes on with severe pains which are too often considered "rheumatic," while the bone-softening process appears to commence in the pelvis, being accompanied by more or less limitation of motion in the hip joint, in consequence of which the patient exhibits a peculiar gait, and sometimes *actually becomes shorter, i.e.,* the body length or height is actually diminished. With changes in the femoral necks the acetabula sink deeper into the sides of the

pelvis, and then begin changes in the pelvic girdle itself. Sometimes the alterations seem to be checked at this point, leaving, of course, permanent deformity of the parts involved; and occasionally it appears that a sclerotic process takes the place of that which had been going on, and final recovery is marked by osteosclerosis, all of which, however, may change with succeeding pregnancy. Should the softening extend to the vertebral column and the throrax, then pronounced deformities are there produced. Their development is nearly always

Fig. 16.—Classical Case of Morand's of General Osteomalacia. (Skeleton in the Musée Dupuytren, Paris.)

accompanied by more or less pain. In the typical complete cases similar softening involves the other bones of the skeleton, while marked deformities occur about the joints, and the shafts of the long bones become more or less bent, the result being a crippling of the entire body, which may be partially or completely disabling. The puerperal forms are, as a rule, more rapid in course than the so-called spontaneous or non-puerperal, the latter beginning most often in the vertebral column.

Somewhat different is the clinical type of cases which are more entitled to the term *fragilitas ossium*—cases in which the changes that have taken place exhibit few or no recognizable features until, with scarcely any violence, a fracture, usually of a long bone, takes place, the circumstances attending it first

calling attention to the unusual frangibility of the bone, and leading to inquiry concerning its cause. Thus occur the so-called "*spontaneous fractures*," the term being a misnomer, yet in such general use as to necessitate its continuance.

Spontaneous fracture is by no means, however, a necessary indication of this condition alone, *since it may be really an expression of the presence of cancer in the bone*. Of these cases in general it must be said that their occurrence should lead, first, to an estimate of the general nutritional condition of the body especially its bony framework, and, secondly, to a careful examination both of the patient's history and of his present condition, in order to exclude the possibility of concealed and perhaps unsuspected *cancer*. A history of previous operation for malignant tumor, or of existence of cancer in the family history, would lend the strongest probability to the belief that the bone at fault had snapped because weakened by this disease. This is one of the directions in which Roentgen's discovery has furnished the greatest aid to the surgeon, since a well-taken skiagram will usually reveal the nature of the condition at a glance.

This is not the proper place in which to consider fracture due to cancer, and our sole purpose here must be some reference to the possibilities of such accidents when bone nutrition is at fault. Syphilis, unless it be accompanied by caries, tends to over-development of bone rather than to its structural weakening, although perhaps behind the nutritional changes which would seem primarily at fault there may be a syphilitic cachexia; but true syphilis of bone, of non-carious character, is usually hypertrophic in its expressions rather than atrophic.

In all probability some at least of the so-called *intra-uterine fractures* are also expressions of conditions similar to those mentioned above. The deformities to which they may lead, or the pseudarthroses, are matters not germane to the present consideration. It is rather with the possibility of their existence that we have to deal. Doubtless in some instances they are due to the so-called *periosteal dysplasia*, by which bone is weakened, even when shaped to the natural type, or hindered in its development until it leads to deformity occurring previous to birth.

The expression *osteopsathyrosis*, introduced by Lobstein, has reference rather to the existence of bone fragility appearing in different members of the same family, or having at least hereditary features. Lobstein especially called attention to instances of this character involving several generations, and occurring in previously and otherwise healthy individuals; but, when once occurring in them, being produced by changes from which they do not subsequently become free; so that, fracture once occurring, the individual is for the rest of his life subject to similar accidents. This tendency may appear in early childhood or not until adult life is reached. Thus, Arnott has reported a child of fourteen that since its third year had over thirty-one fractures, and Blanchard, of Chicago, some years ago, published the case of a woman, then twenty-seven years

of age, who had, up to that time, sustained over one hundred fractures; in her case it being merely necessary to slide her gently from the sofa to the floor to break some bone.

Another very important form of bone softening is met with in certain *insane patients and others who suffer from various diseases of the central nervous system.* Grossly, the bone changes lead to nothing more conspicuous than a possible diminution of measurement. The internal condition, however, is one of marked porosity or sponginess, with partial disappearance of calcareous salts, the result being an extremely fragile structure which permits of fracture on small violence. Injuries in such individuals may assume considerable medicolegal importance, since in an asylum, for instance, the physical force required for the humane and even gentle control of a maniacal patient may nevertheless be sufficient to produce multiple fractures, especially of the ribs or arms, as would be quite natural when making such restraint. Thus I recall one instance that occurred in a state hospital, whose officers and attendants were charged with gross cruelty, in that numerous fractures of the ribs were found in the case of a certain patient dying after an acute mania had run its full course. The newspaper sensation which was made out of the incident led to a legal investigation and even to a suit for damages. In this case I was able to demonstrate before the jury that portions of the ribs taken from the patient's thorax were so fragile and weakened that it was an easy matter almost to pulverize them between the fingers. Needless to say, the damage suit was quashed.

Nor is insanity the only form of mental and nervous disease in which this condition may occur. While it is not an invariable accompaniment of every such case, it may be of almost any of them, at least in some form and to some extent. Here, again, the condition would seem a primary failure or fault of nutrition, and it would be practically a waste of time were we at this point to try to follow the changes further, or to describe them more accurately. It is a recognition of the fact which is here especially to be emphasized.

As between deformity and fracture, then, it is a question of just the extent to which absorption of calcium salts or other structural weakening of the bone shall have occurred, and it is scarcely likely that one may ever see two cases exactly alike. This, however, is of minor importance. The main thing to remember is that deformity and fracture may alike result, deformity gradually producing changes which distort more or less of the whole skeleton, while fractures succeed one another as accident or circumstance may determine. A more careful inquiry into the subject, with a study of its literature, will reveal illustrations (pictorial) of all imaginable forms of alteration. There are the somewhat historical cases of Billroth and Dupuytren, and many others, with the specimens which may be seen in the larger pathological museums of the world, especially those of Paris, Vienna, and London, where all sorts of distortions and crippling changes have been collected. One might fill pages with repro-

ductions of pictures from other works, which might perhaps serve to make the subject more impressive, but which would shed no light upon the pathology and which should not be needed to impress the possibility of these atrophic and regenerative conditions in bone.

While giving up the attempt to find a suitable explanation for even a large proportion of these cases, one nevertheless must feel that he may include acute starvation, or that more chronic expression of insufficiency of food that comes with pregnancy, when the needs of the developing fœtus call for more calcareous material than is furnished from without, so that its mother's tissues are deprived of it; or, again, that form of starvation in which intra-uterine development is limited because the mother has an insufficient supply of general nutritional material; all of which cases would come under the head of general and nutritional changes. The rôle which certain parts of the nervous system may play was acknowledged at the outset, and by allusion to the "trophic" nerves. Without knowing exactly what is meant by this expression one may nevertheless feel that the governing influence, be it what it may is occasionally disturbed, and that control of that which presides over nutrition is lost That heredity is not a negligible quantity would also appear, and that syphilis, acquired or inherited, cannot be neglected is shown by the good effects which sometimes follow the administration of antisyphilitic remedies. Finally, those mysterious influences, which have been elsewhere alluded to in this article, and which exist between the genital glands and some of the other special glands of the body, with their so-called internal secretions, and with perversions of the same, cannot be disregarded, although they cannot at present be pursued to any very exact or profitable issue.

So far as *treatment* of these conditions is concerned one may say the same here as has been said elsewhere in this article: nutrition must be regulated, if possible, and when calcium salts are deficient they must be administered, even though the greater portion thereof be passed again out of the system and found in the excretions, thus showing a failure to utilize them. Calcium phosphate and glycerophosphate, and phosphoric acid, will probably always have a certain indication in many of these cases, but can scarcely be relied upon alone. That *opotherapy*, including administration of ovarian, thyroid, or pituitary extract, is worthy of trial, increasing experience has shown. Nevertheless, it is difficult to tell without experiment just which of the animal extracts is needed in a given case. If little that is encouraging or accurate can be said regarding the general treatment of these cases it is at least comforting to realize that few of them tend of themselves to shorten life, save by accident. In this respect they present a pleasing contrast with some of the hypertrophic forms, such as acromegaly and leontiasis.

Ostitis Fibrosa.

Ostitis fibrosa is essentially an *osteomalacia deformans*, which may appear in isolated portions of the skeleton or involve its entire structure, the bone substance disappearing by process of resorption, accompanied often with formation of small cysts, either hemorrhagic or containing clear fluid, formed apparently by separation of portions of the œdematous marrow and tending to increase by escape of blood. There are often found giant-celled growths which, however, do not seem to be actual giant-celled sarcomata, but rather inflammatory new formations, which in the course of the disease develop in the more solid fibrous structures. Both abnormalities are usually met in the same case. While the disease has usually a fatal tendency it may nevertheless pursue a very slow course, extending over years.

This particular type of bone disease will also explain many cases of so-called spontaneous fracture which have been reported in literature and noted in clinical experience, and which have hitherto seemed almost without rational explanation. In a case recently reported by Gaugele, inside of four years ten of the bones suffered fractures. While some of these may be due to syringomyelia and to other cord lesions, certainly some at least have been due to ostitis fibrosa. A more complete recognition of this condition has been only possible since we have been able to utilize the cathode rays, as will appear in any well-taken skiagram.

Brunn has recently shown in a brief, illustrated article (*Beiträge zur klinischen Chirurgie*, Vol. I., p. 72) that spontaneous fracture is in fact one of the earliest indications of the condition and that it may also easily lead to the early occurrence of various deformities due to alterations in the normal shape of the skeleton. He shows furthermore that one must distinguish between this condition and the development of myelogenous sarcomata, in skiagrams if possible, and at all events clinically, since the existence of the latter would call for excision or amputation not justified by the milder condition.

Marie's Disease.

Other deforming types of changes in the bones are known to follow the occurrence of certain intrathoracic diseases, for instance, which have been especially described by Marie, and to which he has given the name "*ostéo-arthropathie hypertrophiante pneumique*" (*Revue de Médecine*, 1890). Since Marie's paper appeared Bamberger and Lefebvre have furnished additional studies, all bearing on this interesting question. Some of these cases are characterized by considerable augmentation in the size of the extremities, the soft parts participating as well as the bones themselves. In some of the pronounced cases nearly all the bones of the body have become involved, while the hands

especially have increased in size, the fingers being enlarged, the flat bones undergoing a thickening, and the spine developing a marked kyphosis. Some of these bone changes are accompanied by quite severe articular pains, and nearly every patient thus affected shows more or less cachexia. This seems to be a different disease from acromegaly, which is characterized especially by spontaneity, and by involvement of the cranium and jaw —alterations which are not noticeable in Marie's disease.

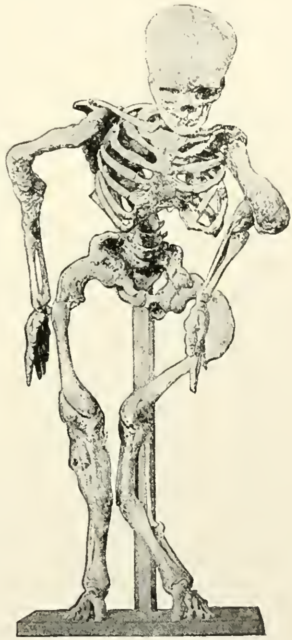


Fig. 159. Ostitis Deformans (Paget's Disease) with Osteophytes and Osteomata. Skeleton of a woman of forty. (von Recklinghausen.)

These conditions are more often noted as sequels of pneumonia, pleurisy, and their complications, especially empyema, than of tuberculous chest diseases. Nowhere is furnished a satisfactory explanation for the sequence, and a discussion here of etiology would be impossible.

Ostitis Deformans.

There is much in the condition just described to remind one of the *ostitis deformans*, first described by Paget, and often spoken of as *Paget's disease of bones*. Its significant feature is augmentation of size and more or less deformity, especially of the long bones, while those of the trunk and the cranium may show similar, yet less conspicuous, changes. (Fig. 159.) Paget's disease curs in elderly patients, and its manifestations may be limited to but a small portion of the entire skeleton. Section of bones thus affected shows a more or less complete obliteration of their medullæ, with the formation of cysts and accumulation of giant cells. The result of the combined changes is such as to permit of more or less bending and distortion, as well as of osteophytic outgrowth. Recklinghausen has referred the disease to vascular disturbances, especially including venous stasis, and he has compared many of these bone changes to elephantiasis of the skin. The truth probably is that in the so-called Paget's disease two or three different types of bone changes are included, *trophoneurotic atrophy* and *irritative hypertrophy* proceeding perhaps simultaneously and side by side, and in this way producing the characteristic deformities. Inasmuch as these changes occur primarily in the bones, the entire disease is to be *distinguished from ar-*

thritis deformans, in which the pathological processes commence rather within the joint structures, and in which the osseous changes are quite secondary. When the bones of the head are most involved, they are usually those of the face. The thorax becomes more or less cubic in form, the arms perhaps relatively too long, the ribs increased in size, while the pelvis may be distorted. The patellæ are also enlarged, the tibiæ become more massive and their curves more exaggerated. Save in those rather exceptional instances above alluded

a

b

FIG. 160.—So-called "Ossified Man." Osteoarthritis with True Ankylosis of nearly All the Joints. (From the Park Collection in the Museum of the University of Buffalo.) *a,* Front view; *b,* side view.

to, where the disease seems local, it is essentially a symmetrical series of lesions which begin, as often perhaps as anywhere, in the cranium and ribs.

In ostitis deformans fractures are rare, since the bones are hardened and strengthened rather than weakened as the result of the sum of the changes. The majority of patients suffer more or less severe pain, often aggravated by pressure. In the earlier stages, at least, the disease is quite likely to be grouped with many other bone diseases as so-called rheumatism. Its most conspicuous features are, briefly, deformity, with final crippling, and the pain which it produces. (Fig. 160.)

There remain yet to be mentioned in this connection the other bony changes

which have been described in connection with so-called *Charcot's disease of joints*, *syringomyelia*, and *tabes*, all of which may be rudely grouped under one head, and between which it is very difficult to make out distinctive or diagnostic differences. Remembering that in all of these conditions the central nervous system seems primarily at fault, we probably have a right to assume that they are the result of a perversion of nutrition permitted through some fault of the trophic nerves. While recognizing the vagueness of this statement, one finds it at present impossible to be much more definite.

The changes ensuing upon these various diseases are in some instances slight and trifling, causing but little disturbance or suffering, and so they may remain throughout the rest of the patients' lives. Probably the majority of them are, however, progressive, some slightly, some rapidly so, while in a certain, fortunately not very large, proportion they become sadly crippling and distressing. They constitute essentially a combination, like that met with in Paget's disease, of rarefying and sclerosing processes, which produce absorption at one point and hypertrophy or osteophytic outgrowth at another, the result being strange transformations of natural contour, with secondary changes in adjoining joint structures proper, often accompanied by accumulation of fluid, the entire result being to transform what was once a joint into something strangely different, which may be not only useless, but more or less painful and disabling. While one knee, for instance, may be involved in one way, the other may be quite differently altered, the result being a lack of that symmetry which is apparently observed in certain other forms of disease.

Unfortunately, all of these conditions admit of little or nothing in the way of successful treatment. Some compensation may be afforded by apparatus, or some relief obtained by tenotomy or other surgical measure as suggested by the exigencies of a given case. In general, however, no directions which are either explicit or scientific can be laid down. Every case must be studied and treated upon its merits, and any surgical procedure may be instituted which seems to be adaptable, from the production of an ankylosis to the exsection of a joint or even the amputation of a limb.

SYPHILITIC DISEASE OF THE BONES.

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GENERAL CONSIDERATIONS.

Syphilitic disease of bone, like syphilitic disease of other tissues, imitates various pathological affections. This, as is well known, is a characteristic of the disease and is as faithfully followed out when the bones are attacked as when the soft structures are involved. There is no one feature that is entirely pathognomonic of syphilitic disease of the bones, as is the case with tuberculosis or malignant tumors. The history of the patient and the presence of the lesions elsewhere constitute the most important reasons for the diagnosis. In tuberculosis the typical tubercle with its giant cell and bacilli can be found by faithful search; malignant disease, whether it be sarcoma or secondary carcinoma, also presents special characteristics; but there is probably no pathologist who would venture to make a diagnosis of syphilitic disease of the bone solely upon the appearance of a section of the tissue. The essential lesion is a gumma, which holds the same relation to the late stages of syphilis as the tubercle does to tuberculous disease, but the gumma is merely a mass of granulation tissue and to the naked eye often presents the appearance of ordinary granulations. The feature about gummatous tissue that is not often met with in other conditions in such a pronounced degree is the marked thickening of the arteries. This is always noticeable and is due to the excessive amount of connective tissue formed during the progress of an obliterating endarteritis, which is caused by the irritating effects of the syphilitic virus. Tissue which presents unusual thickening of the blood-vessels, while the other appearances indicate granulation tissue, might very justly be held to be most suspicious of syphilis.

A gumma is of a grayish appearance, sometimes pinkish in color, and varies in size from microscopical dimensions to a tumor several inches in diameter. The larger-sized gummata are due to the confluence of a number of smaller ones. They may be circumscribed, but are very rarely encapsulated. The microscopic picture shows the small round and epithelioid cells of granulation tissue and occasionally a giant cell; trabeculæ are present in very small amount. Hyaline degeneration, followed by fatty degeneration, may change the centre of the gumma into caseous material. These changes are probably due, in part at least, to the thickening of the walls of the blood-vessels, which sometimes proceeds to the point of obliteration of their lumen, thus cutting off nutrition

and hastening degeneration. Very occasionally, secondary infection gives rise to suppuration. When necrosis begins, it extends peripherally, though necrosis and ulceration do not always occur in gummata. In the early stage the gumma is hard, but later, when degenerative processes have set in, caseation and softening appear, somewhat as is the case in the later stages of a tubercle, and the centre of the mass then resembles the contents of a cold abscess. Gummata sometimes appear as multiple nodules, though more often they occur singly. When multiple they are found at the same time in different tissues and organs. The periosteum is one of the most frequent sites. In its later stages a gumma may undergo calcification or absorption, or it may manifest a tendency to extend and eventually to break down, the infected tissue undergoing conversion into a necrotic mass.

While the course of the majority of gummata is generally like that which we have just described, not a few of them behave somewhat differently, these differences depending in great measure upon their location. For instance, when a gumma appears upon the exterior of the skull it is at first soft, and becomes firm only later on, as the bone cells beneath develop as a result of the inflammation of the periosteum and bone. Fournier quotes an unusual case in which the left humerus contained in its lower portion a large gumma, which on section was seen to be partially separated from the surrounding bone and presented the appearance of being encapsulated.

It must be remembered that whatever may be the cause of syphilis, whether due to a micro-organism or whether the infection is conveyed in some other manner, the toxin seems to be irritating to all tissues, and in certain stages of the disease, as in the tertiary or in the hereditary, this irritating action is most pronounced. The indirect effect upon the bone, such as necrosis, is often due to the excessive proliferation of connective tissue in the blood-vessels, as a result of which the bone is deprived of sufficient nutrition. In the early stages of syphilitic infection the blood-vessels are abundant, and, before thickening of the vessels has advanced too far, the nutrition of the bone is excellent. This probably accounts for the infrequency of actual necrosis of the bone. The ample blood supply in the early stages seems sufficient to combat infection, the lodgment and proliferation of pyogenic germs being hindered, and consequently the destruction of tissue being less than would otherwise be the case.

THE VARIOUS FORMS OF SYPHILITIC BONE DISEASE.

It may be well to take up in a general way the various forms of syphilitic infection of the bones before attempting to make a more concrete application to the acquired or to the hereditary stage of the disease.

Syphilitic periostitis is first manifested by hyperæmia. The pain, however, is much less than is usually found after acute periostitis of pyogenic origin.

The ordinary phenomena of this disease, such as the presence of large quantities of lymphocytes, dilatation of the blood-vessels, and local œdema, occur and are usually confined to one spot. Later, typical gummata appear, sometimes only a single one, at other times several, and form nodules of the same general histologic character as that already described. The disease may be arrested at this point, and, if such be the case, the periosteum may return to its normal state; or suppuration may set in, although this is unusual in the early stages of a gumma; or, finally, the thickening may continue and an excessive amount of bone may be produced, an excess which is likely to be permanent.

The *ostitis of syphilis* is even more distinctive of this disease than is the periostitis. In general, it may be divided into two forms, the rarefying and the productive or condensing. The rarefying occurs first and is either followed or accompanied by the productive form. In rarefying ostitis the Haversian canals are filled with small round cells resembling leucocytes, which extend into the adjoining portion of the bone marrow. These cells are the typical round cells accompanying ordinary inflammation. The vessels are dilated and some exudate is present. The bony trabeculæ separating the Haversian canals become thin and gradually disappear by absorption. This makes cavities much larger than those found in normal bone, as several Haversian canals are formed into one cavity by the absorption of the bone surrounding them. The disease gradually extends, and vascular processes shoot out into the surrounding bone. Later on, rarefying ostitis is accompanied or followed by productive ostitis. The phenomena here are just the reverse of those in the rarefying type and consist in the deposition of lime salts; that is, the phenomena point to the formation, and not to the absorption, of bone. The Haversian canals become partly filled with compact bone and may be completely obliterated. On account of the great compactness of this bone it is exceedingly hard, and the process by which it is formed is called "eburnation."

Rarefying ostitis is found in other diseases, but condensing or productive ostitis, when accompanying the rarefying type, is characteristic of syphilis. Frequently in syphilitic infections of the skull there may be great loss of bone substance, resulting in thinning or even perforation of the skull, while along its edges will be found an increased amount of bone of great hardness which has been produced by condensing ostitis. One of the peculiarities of syphilitic ostitis is that, after loss of bone as a result of this infection, but little attempt at filling the defect is made. Thisis particularly noticeable after loss of bony substance about the skull and face, and is often seen after perforations of the palate bone or destruction of the nasal bones (Figs. 161 and 162).

Syphilitic ostitis is not usually followed by necrosis and the separation of sequestra, although this sometimes happens. Caries is a more common form of destruction. This may be due to the abundant blood supply in syphilitic tissues which was mentioned in describing the early stages of a gumma. Later

on, when the arteries become partly closed by the typical endarteritis, and the condensing form of ostitis obliterates many of the Haversian canals and so cuts off nutrition, bone may die in larger amounts and sequestra separate. This occurs more frequently in the bones of the face and in the skull.

Fig. 161.—Cranium showing the Lesions of Syphilis chiefly in the Crown and External Table. The bones show various degrees of absorption and destruction, amounting to complete absence in some places where larger fenestræ are seen. Evidences of hypertrophy and new growths are also visible. The patient, who is said to have been the "funny old lady who was an upper domestic" mentioned by Dickens in his "Notes of American Travel," chapter xiv., died of syphilis, when over sixty years of age, in the almshouse at Norwalk, Ohio, in 1868 or 1869, under the care of Dr. A. N. Read. (From the Hamilton Collection, U. S. Army Medical Museum.)

Osteomyelitis of syphilitic origin is never productive of the same intense pain and general constitutional symptoms that the acute form of osteomyelitis

causes, though it indicates a more serious affection than either the periostitis or the ostitis referred to above. It begins near the diaphyses, and produces a gnawing, constant pain, which, like other pain resulting from syphilitic disease of the bone, is worse at night than during the day. It may extend, and the resulting gummatous mass may break down. The contour of the bone is al-

Fig. 162.—Calvarium showing Thickening, Exostoses, and Perforation; from a man, aged forty-seven, who died of tertiary syphilis. The dura mater showed thickened patches on the internal surface of the bone. (U. S. Army Medical Museum, Washington, D. C.)

ways affected if the osteomyelitis is not too limited. The process may be so circumscribed as to be surrounded by a distinct capsule, although this is not usually the case. If the product of the gummatous osteomyelitis breaks down, the joints are occasionally involved from perforation of the bone in that direc-

tion. When suppuration from the lodgment of pus germs occurs, the symptoms take the typical form of those belonging to pyogenic osteomyelitis with rapid destruction of bone, and the characteristics of this latter disease will then manifest themselves. When syphilitic osteomyelitis affects the skull and involves the diploë, the two tables of the skull may be forced apart, extensive necrosis of the outer table resulting from the forcible cutting off of nutrition.

The feature that is peculiar to all syphilitic diseases of the bone is the so-called "*osteocopic pains*." These have not been satisfactorily explained, although Ricord says they are due to the increase of circulation in the capillaries which is caused by the warmth of the bed. As a matter of fact these pains are worse at night in people who work during the day, but in others who sleep during the day and work at night the pain is more severe during the day. It is difficult, however, to see the logic of this explanation in every case, for in many instances continued activity would certainly increase the circulation to a great extent, while the warmth of a bed would cause dilatation of only the superficial vessels. The recumbent posture does not increase the heart action or blood pressure, but actually diminishes these, and for this reason, while there may be more abundant circulation in the superficial capillaries, the blood pressure in the vessels of the bone would appear to be less when the patient is in bed than when he is actively engaged in manual work. It is more probable that the pain is due to diminished blood supply from the decreased blood pressure in the recumbent position through the partially occluded arteries, the nerves thereby suffering from anæmia. It is unquestionably true, however, that at certain periods, which apparently correspond to the time when the patient is in bed, the pains are much more severe, and this is one of many symptoms that should excite suspicion in bony diseases the diagnosis of which is not entirely apparent.

Acquired Syphilis.

The bony lesions of acquired syphilis may partake of any character. There may be periostitis, ostitis, or osteomyelitis, or any combination of these. As a matter of fact, it is more common to find a combination than only one form. Periostitis is usually the form in which acquired syphilitic osseous disease first manifests itself. Although periostitis may be the main feature in the case, nearly always the superficial layers of the bone are affected at the same time; and when the outer portion of the bone is involved the periosteum is usually diseased. While it is true that syphilis in its tertiary and hereditary stages is peculiarly liable to attack bone, at no period are bone and its membranes entirely immune. The following case, which is quoted from Mauriac, well illustrates this:

The patient was a man thirty years of age, of previously good health. Periostitis of the frontal bone appeared thirty-four days after chancre and four days before

the first eruption. Periostitis of the internal malleolus made its appearance two days after the affection of the frontal bone. The chancre developed on February 1st. On March 3d there were extreme headache, fever, and sweating at night, with no other signs of general infection. Potassium iodide was ordered. On March 6th, in spite of treatment, a node appeared on the left side of the frontal bone, and, two days later, periostitis developed at the right internal malleolus. On March 10th, after the periosteal tumor had increased to a marked extent, the typical roseolar eruption appeared. Under proper treatment the patient made a rapid recovery.

While such an occurrence as that just described is very unusual, it is well to bear in mind the possibility of an early development of affections of the bone. It has been thought that this indicates a very severe attack of the disease, although in the case above mentioned recovery followed treatment without any particular complications. In the secondary stage of syphilis, disease of the bone is more common than in the primary. The frontal bone is the part particularly liable to be affected, and syphilitic periostitis is the usual form manifested by the disease. The tibia comes next in frequency, and then the ribs.

In the tertiary stage of syphilis, the osseous system is attacked more frequently than any other part of the patient's anatomy, except the skin. The syphilitic inflammations of the periosteum and of the bone usually occur together, although they may exist alone at the beginning of the attack, and doubtless throughout the whole attack, when the only symptom is transient osteocopic pain or transient puffiness of the periosteum. Unless resolution rapidly occurs, the inflammation in one tissue spreads to the other. It is probable that the osteocopic pains, which are early signs of the inflammation of the bone or periosteum, are always due to actual organic disease of the bone or its membrane. This seems to be borne out by post-mortem examinations in cases in which osteocopic pains were the only symptom and there was no demonstrable lesion, yet exostoses on the inner table of the skull corresponding to the painful area of bone were found. The syphilitic virus attacks the periosteum or the superficial layers of bone early in the tertiary stage. There results immediately the development of a node in the periosteum, this node consisting of thickened periosteum, and the thickening in turn being dependent partly upon a serous exudation, partly upon the accumulation of small round cells. Hyperæmia, with the formation of new blood-vessels characteristic of all syphilitic inflammations, occurs at the same time. The bone then becomes roughened over a limited area (Fig. 163) and an exostosis may result (Fig. 165). If there are a number of these places along the same surface the whole shape and size of the bone may be changed, and this is referred to as a hyperostosis. (Fig. 175.) The inflammation is sometimes so severe at first as to cause an abscess and necrosis of the bone, although it is more usual for the gummatous form to succeed this simple periostitis. However, the inflammation, instead of beginning in the periosteum

or in the superficial layers of the bone, occasionally commences well within its substance, and when this happens the disease is apt to proceed to molecular death of the bone and to a condition of caries, surrounded by the productive ostitis and the eburnation that are so characteristic of syphilitic disease of the bone. (Fig. 175.) Necrosis may sometimes occur. The gummatous form of inflammation of the bone or periosteum is a later stage, in which the granulation tissue which ordinarily accompanies this inflammation becomes more localized and

FIG. 163.—The Vault of the Cranium, Showing Syphilitic Ulceration of the Left Parietal and the Frontal Bone. (From U. S. Army Medical Museum, Washington, D. C.)

more permanently formed. In the irritative form of inflammation the gumma has a marked tendency to destroy bone, although resolution may still be possible.

Syphilitic osteomyelitis tends to caries, while pyogenic infection produces necrosis of bone and will cause intense constitutional symptoms. In some cases, where absorption has taken place from rarefying ostitis or from caries, the bone may be reduced to great thinness and may be so frail as to fracture readily. However, this condition, which has been referred to under the head of "Rarefying Ostitis" (p. 366), is not so characteristic of syphilis as is eburnation, which

results from condensing or productive ostitis. In the gummatous form the deposits vary in size from that of a pin's head to that of an object several inches in diameter, and may cause caries or even necrosis within the bone, without affecting the skin situated over it. Under these circumstances it often happens

Fig. 164.—Cranium of an Indian, showing Absorption of the Frontal Bone by Syphilitic Ulceration. (From U. S. Army Medical Museum, Washington, D. C.)

that portions of bone are separated as sequestra and may be recognized as rough masses on palpation. They sometimes require operation for removal, and in many instances fracture results from the loss of bony substance. In other cases, where the sequestra have not been expelled, union of the fractured fragments will take place. Atrophy of bony substance, in contradistinction to

osteoporosis, may be seen in one or all of the bones, but it is more probably due to malnutrition than to any direct action of the virus of syphilis, although some authorities do not accept this view.

Fig. 165.—Cranium of a Female, showing the Inner Table of the Frontal Bone Completely Covered with Exostoses that vary in thickness from one-half to one-eighth of an inch. It was also found that exososes had formed on the lower part of the right orbit and on the upper portion of the right maxillary bone. (From U. S. Army Medical Museum, Washington, D. C.)

As has been mentioned, the caries in syphilis is more or less characteristic and is usually of the dry variety, in which no fluid exudes between the peri-

osteum and the bone. It occurs chiefly on the cranial vault, in isolated spots both on the external and the internal surfaces of the skull. Under the influence exerted by the new formation of blood-vessels that advances from the dura or the pericranium, the bone trabeculæ become absorbed and there is

FIG. 166.—Front View of the Skull Shown in Fig. 165. Note the exostoses in the right orbit and on the right malar bone. (From U. S. Army Medical Museum, Washington, D. C.)

formed a pit that is filled with small round cells and new granulation tissue. Such a depressed area may often be felt through the skin when the scalp is not invaded and ulcerated. From this pit, as a starting point, canals in the diploë and on the surface are hollowed out by absorption in a radiating manner. A

post-mortem examination of such a case will show the inner and outer surfaces of the skull traversed by tortuous and worm-eaten grooves. The infrequency of the presence of pus in such a condition is explained by the fact that the granulation tissue possesses an abundant blood supply. Later, how-

Fig. 167.—Cranium Showing Destruction of the Nasal, Ethmoid, and Palatal Bones by Syphilis. (From U. S. Army Medical Museum, Washington, D. C.)

ever, when condensing ostitis sets in, the nutrition may be reduced to such an extent that the tissues break down and local necrosis and suppuration result. Around these grooves and pits in the skull the condensing ostitis forms a raised ring, in marked contrast to the excavated portions.

Syphilitic necrosis following gummatous inflammation presents peculiarities. According to Virchow the sequestrum is separated from within outward, so that it presents a worm-eaten appearance on its inner surface, while the external surface is comparatively smooth. The edges of the living bone at the line of separation are swollen and thickened by the condensing ostitis in a

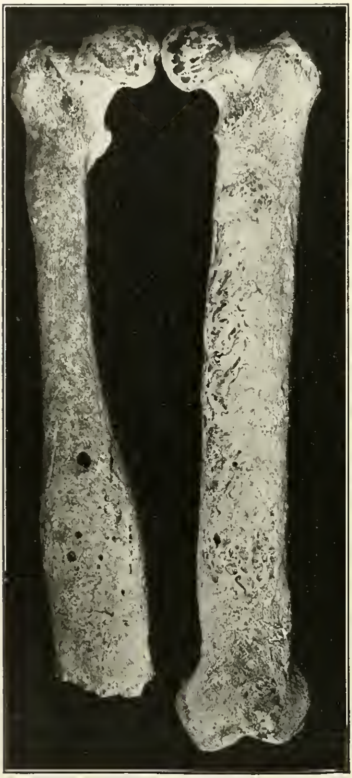

Fig. 168.

Fig. 169.

Figs. 168 and 169.—Syphilitic Disease of the Right and Left Femurs (Fig. 168) and of Both Tibias (Fig. 169). The same patient furnished the skull represented in Fig. 164. (From U. S. Army Medical Museum, Washington, D. C.)

way very characteristic of syphilitic necrosis. Syphilitic necrosis often occurs in bones of the skull and face, where it causes marked destruction. The formation of gummata in the region of the diploë, between the inner and outer tables of the skull, often so cuts off the nutrition to the outer table by pressure as to produce extensive necrosis. When the necrosis is limited the tendency

of the sequestra is to form serpiginous or circinate margins which resemble very much the outlines of the skin lesions in tertiary syphilis.

All scars, after syphilitic destruction of the bone, are peculiar in one respect: there is no formation of bone to build up the centre of the cavity, al-

FIG. 170.—Periostitis, Osteoporosis. Bones of feet (somewhat fragmentary on the left side) show results of syphilitic inflammation: surface of bone somewhat eroded and dotted with fine periostitic growths; some osteoporosis of tarsal bones, especially the calcaneum. (From U. S. Army Medical Museum, Washington, D. C.)

though the condensing ostitis at the margin may be considerable. As a result there is left a fibrous scar, which contracts and draws down the arch of the cranial vault or the bridge of the nose, or else, as happens in some cases, there is a very feeble attempt at filling up, such as may occasionally be observed after perforations of the palate.

In acquired syphilis osteo-periostitis often occurs early, when several bones are generally involved. Under mercurial treatment the manifestations of the disease usually disappear in the course of three or four weeks. It is more common, however, in acquired syphilis, for the bony lesions to appear four or more years after the chancre, and then a single bone, such as the tibia or the clavicle, is the first attacked. The first bone affected is more liable to be destroyed in such a case than are the bones attacked at a subsequent date, when the virulence of the disease has diminished. The frequency with which the different bones are attacked in acquired syphilis may be given in the following order: First, the cranium, especially the frontal bone, the occipital and temporal bones being rarely involved; the bones of the face, particularly the nasal bones; the long bones, those of the leg and forearm being attacked more often than the bones of the thigh or upper arm; finally, the clavicle, the sternum, and the ribs. The vertebræ, the bones of the pelvis, and the other bones in general are rarely affected.

Fig. 171.—Syphilitic Inflammation; Osteomyelitis, Osteoporosis, Ossifying Periostitis. Parts shown in the picture: lower ends of both femurs, and the corresponding patellas, tibias, and fibulas in their entirety. The following conditions are worthy of note: the decided irregularity of the surface, as seen particularly on the front parts of the tibias; the marked depressions and new growths of bone; and the general osteoporosis. (From U. S. Army Medical Museum, Washington, D. C.)

Hereditary Syphilis.

In hereditary syphilis the bones are relatively more frequently involved than in any stage of acquired syphilis. In the tertiary stage the disease seems to affect particularly the deeper tissues and organs, and it naturally follows from this that the bones would be the chief objects of attack in the hereditary form, for the disease has arrived at what corresponds to the tertiary stage in the infant when he is born. It is well known that the growing bones of a very young child are often the site of various osseous diseases. This is due to the growth of the bone and to the consequent immaturity and lack of resistance

of the rapidly forming embryonal cells which produce this growth. Syphilis, then, in common with other diseases, is particularly liable to affect the bone at this stage; and when we take into consideration the lack of resistance of such bone, as well as the late stage of syphilis when it is hereditary, it can be readily seen why a large proportion of lesions of hereditary syphilis are manifested in the osseous system of children and young adults. In the very young there seems to be a marked tendency for gummatous lesions to undergo rapid degeneration. This is not true with advancing age, for after ten years of age it is rare to find hereditary syphilis producing serious necrotic affections of the bone. Of course, caries may be present even in young adults.

It is very common to find degeneration in syphilitic affections of the skull in infants when a few months old, and the lesions in such cases are often followed by the formation of an abscess. When this occurs in long bones, mixed infection, which is more frequent here on account of the tendency to degenerate, may set up acute osteomyelitis, or, breaking into a joint, may cause arthritis. The bony affections in hereditary syphilis are often accompanied by gummata of other organs, and these lesions may cause the patient's death independently of the disease of the bone.

As has been said, in very young children the bones of the skull, particularly the frontal bone, and the long bones are most frequently involved. As the years advance, however, the order of frequency, according to Fournier, is as follows: The tibia is by all means the most frequently affected; then follow the ulna and the radius, the former being more often attacked; after these come the humerus, the femur, the fibula, the clavicle, and all the bones of the skull. The vertebræ, the pelvis and the other bones not already mentioned are very rarely affected. From this statement it will be seen that at a later period of life there is a distinct change in the order of frequency with which the different bones are involved in hereditary syphilis; this change being most marked in the case of the skull, which in early infancy is diseased oftener than all the other bones put together. The exostoses of the skull which are found near the anterior fontanelle are considered by some authorities as very characteristic of hereditary syphilis, and are spoken of as "Parrot's nodes." They are comparatively common in this stage of the disease. The effect of treatment upon the mother is most marked, and may not only delay the time of appearance, but greatly modify the virulence of the disease. It is somewhat peculiar that while a large number of cases is seen during the first six months of life, in the period between two and five years the disease is rarely encountered, as compared with later or with earlier periods. According to Fournier, out of a series of cases of inherited syphilis in children over three years of age, there were 5 in whom the disease developed between the ages of three and five years, 54 between five and twelve years, 24 between thirteen and nineteen years, and 7 between nineteen and twenty-eight years

It is entirely probable, however, that in some cases the symptoms may appear after the twenty-eighth year. When hereditary syphilis affects the skull,

Fig. 172.—Abnormally Curved Bones, a Condition Probably Due to Congenital Syphilis. The affected bones are those of the right thigh, leg, and forearm. (From U. S. Army Medical Museum, Washington, D. C.)

ulceration often occurs, and this result is quite common in very young children. The frontal, parietal, or occipital bone may be involved. Sometimes distinct

nodules are found as a result of syphilitic inflammations of the periosteum, and they persist without degenerative changes. If the ulcerative process involves both tables of the skull, meningitis and death are likely to follow. If the nodules—so-called osteophytes—organize and form bone, they may produce outside changes in the contour or shape of the skull. Often early ossification takes place in certain portions of the cranium, and as a result the head becomes markedly asymmetrical. In a general way, involvement of the bones of the skull in the course of hereditary syphilis is similar in all essential respects to what takes place in the acquired form of the disease. Hereditary syphilis tends to involve all the long bones and sometimes produces premature ossification of the epiphyseal cartilages—a phenomenon which interferes with the growth of these bones and so causes them to undergo marked changes in appearance. On the other hand, a gelatiniform degeneration may, in the very early months of life, produce a separation of the diaphysis from the epiphysis —a change which has been called by Parrot *pseudo-paralysis*. This occurs chiefly in the humerus or in the femur. It is not a true paralysis in any sense of the word. Atrophy of the muscles supplying a joint at which a separation has occurred follows from disuse, and the apparent inability to move the joint is due to this separation and to the pain and muscle spasm which follow when an attempt is made to move the part, just as happens after a fracture in a timilar location. The proper adjustment of these fragments and immobilization of the joint by a splint will usually result in a cure.

When there is early ossification of the epiphyseal cartilage an enlargement is very likely to result. This may appear as a symmetrical enlargement of the end of the long bone, and is seen more frequently in the distal than in the proximal extremity of the bone. Sometimes it takes the form of a distinct tumor, which may be smooth and globular, or sharp in outline, or a collar which extends completely around the end of the bone may result. These formations are accompanied by but little pain. Effusion into the joints often occurs, particularly when the cartilage affected is near the elbow or the knee. Treatment may modify this, as it does in the case of any other form of syphilitic disease of the bone, and thus arrest the deformity at almost any stage.

Influence of Trauma.

The connection between trauma and affections of various bones, both in acquired and in hereditary syphilis, is somewhat interesting. It is claimed by many that the bones most subject to trauma are those particularly liable to develop syphilitic lesions. To some extent this appears to be borne out by the relative frequency of involvement of various bones. For instance, in infants only a few months old the head seems to be the particular object of attack for this disease. It is well known that in infants the brain grows more rapidly

in the first few months than any other portion of the body, and consequently it is thought by some observers that there is more strain upon the bones of the skull during this stage. Later on, when the child begins to walk, small injuries are liable to occur in such superficial bones as the tibia. These are the bones that would be expected to be most frequently involved according to this theory, and statistics show that this is the case. Deep bones that are well preserved from injury, such as the vertebræ and the bones of the pelvis, are seldom affected.

Fractures.

Persons afflicted with hereditary syphilis are more subject to fractures than are healthy individuals. Sometimes bones, on account of this disease, are exceedingly fragile, but, as a rule, if a fracture occurs, union takes place readily. This is particularly true when antisyphilitic remedies are given at the time the fracture is being treated. There seems, however, to be a popular belief that fractures in patients suffering from syphilis, either hereditary or acquired, do not readily unite. The writer had under his observation a case which illustrates many points in hereditary syphilis, as well as the healing of fractures and the results of bone operations in syphilitics; and he believes that it is of sufficient interest to report in some detail:

The patient was a girl seventeen years of age when she came under my professional care. There was a distinct history of syphilis on the side of both her mother and her father. She was born with no left hand, and a very short, deformed left forearm. She had crowded teeth, some with slight ridges, though not markedly typical of Hutchinson's teeth. Her right forearm, although apparently normal in general outlines, showed on the distal extremity of the radius marked symmetrical enlargement, which was not painful and had existed ever since she could remember. There was slight bowing of the bones of the legs. When eight years old, having been apparently in good health previously, she had two "boils" over the tibia on the right leg, from which small pieces of bone worked their way out. From this date onward there have developed on both tibiæ, at intervals of a few months, nodules which occasionally form abscesses. In 1897 the right tibia became much worse than the left. Several abscesses appeared and left behind them large masses of bone from which no distinct sequestrum formed, but which presented evidences of extensive caries. Some of these ulcers, having diseased bone as a base, refused to heal, and gradually became worse. In 1899 the patient was treated in one of the large city hospitals of the West, and was finally operated upon. She was given large doses of potassium iodide. She reported that the surgeon did not open the cavity of the bone, but merely incised the periosteum. At the end of six months she was discharged with her leg still unhealed, and told to continue the iodide, which she did faithfully. On April 16th, 1901, while merely walking on a level surface, her right leg broke at about the junction of the middle and lower thirds of the tibia, at a point where there was a large ulcer and where the bone was markedly diseased. She came under my care four days later. An operation having been decided upon, she was brought under the

influence of chloroform. This anæsthetic was selected because she gave a history of having had considerable bronchitis, although no decided lung trouble was present. After the periosteum had been stripped away, the diseased bone was chiselled until the medullary cavity lay open from the point of fracture to the upper portion of the shaft. Some necrotic bone was found and also a considerable amount of pus, which latter may have been due in part at least to mixed infection following constant ulceration at the point of fracture. The caries was so extensive on both ends of the fractured shaft that no healthy bone could be preserved at these points. The odor was very offensive. The periosteum was stripped up and a section of the bony shaft about three-quarters of an inch long was sawed off with a Gigli saw from each end. Two holes were drilled in each end of the resected tibia, and approximation was obtained by means of silver wire. The fracture of the fibula was not compound, and the ends of this bone were merely overlapped. It was deemed unwise to perform an operation on the fibula that would expose this bone to the risk of infection from the badly infected tibia. The wound was drained with iodoform gauze and the leg was put in a plaster-of-Paris dressing. At the end of a week a fracture box was substituted. There was slight suppuration, but the wound healed nicely by granulation; and after the lapse of four months the bone had firmly united and epidermization was complete. Two weeks later a sinus formed in the vicinity of the silver wire and both of these sutures were removed. The bone continued firm, but from time to time the scar over the bone broke down in two or three small spots. Inasmuch as the patient showed a tendency toward bronchitis and a rather weak heart, and also because the amount of scar tissue was large and the local nutrition poor, it was thought best not to resort to the use of skin grafts. It was also decided to discontinue the potassium iodide, which she had taken in large doses for over two years, and to give general tonics instead. Six months after the operation the skin had satisfactorily healed and showed no tendency to break down. A shoe with a cork sole of an inch and a half elevation was put on the right foot. This compensated for the amount of bone taken out at the time of the operation, and she was able to walk with comfort and with a scarcely perceptible limp. A year later, the tibia of the left side became so painful that it was thought best to operate upon it. The bone was found to be much less extensively diseased than it was on the right side. Healing took place slowly. At intervals of a few months there would be small patches of superficial necrosis, with local periostitis developing over the inner surface of the tibiæ of both legs. These patches usually developed as a result of some slight trauma. On each of these occasions the necrosed bone was removed by an operation performed with the aid of cocaine anæsthesia, and in each instance the subsequent healing took place slowly. The intervals between these attacks sometimes lasted for several months. Her general condition had greatly improved.

The case is of some interest as illustrating the marked persistence of the disease, its confinement to both tibiæ (with the exception of the enlargement of the distal end of the radius, which, however, gave her no pain or inconvenience), and the resistance of the bony disease to antisyphilitic treatment. The congenital deformity of the left forearm and hand; the satisfactory result obtained after extensive operation upon the right tibia, including resection of an inch and a half of its shaft; and the firm union of the divided ends of the bone

—notwithstanding the suppurative process and the extensive disease of the bone—are also points worthy of note.

Syphilitic Dactylitis.

Dactylitis is one of the numerous phases by which either tertiary or hereditary syphilis may manifest itself. It consists of a gummatous inflammation of the fingers or toes, the fingers being more frequently affected than the toes. It may begin in the connective tissue or ligaments surrounding the joint, in the periosteum, or in the bone itself. When Dr. R. W. Taylor wrote the first important paper on this subject, in 1871, only five cases had been recorded. Since that time, as a result of more careful observation, a number of other cases have been reported; consequently, this affection is no longer considered as rare now as formerly. It does not differ materially from other forms of syphilis that appear in the tertiary or the hereditary stage. It frequently occurs in the hereditary form in early childhood, and, like what is characteristic of most other bony syphilitic diseases during this period, there is a marked tendency to degeneration and ulceration. Generally, the middle and ring fingers are more often involved than the others, although all have been attacked.

Fig. 173.—Hereditary Dactylitis Syphilitica. (Erich Lexer: "Lehrbuch der allgemeinen Chirurgie," 1904.)

Two varieties of dactylitis are frequently reported. In the first kind the connective tissue under the skin and the ligaments of the joints are involved. As the disease advances slowly, the finger—or the toe, if this be the part affected—gradually increases in size, becoming firmer and harder. The skin is bluish-red in color and the swelling of a fusiform or spindle shape, more marked on the dorsal surface, as a rule, and terminating at the metacarpo-phalangeal joint. Unlike the ordinary gumma, which usually forms a well-marked tumor, in this variety no distinct tumor can be made out when the subcutaneous tissue is first involved. One finger or toe may be attacked, or several digits at the same time, the entire length of the member being usually affected. If the condition is left untreated, it runs a chronic course and produces marked deformity, resulting in loss of tissue; indeed, shortening of the finger is not an uncommon result. In some instances, the whole length of the finger or toe is not involved, the disease being confined to a single joint. Occasionally, too, the metacarpal bones are the seat of dactylitis. In the majority of cases the swelling disappears under treatment, without the formation of an abscess, but this statement does not apply to infants and very young children, in whom

the tendency to degeneration is marked. The nails generally remain unchanged, even though the tips of the fingers be involved. In the course of the disease the fibrous tissue around the joints is invaded by gummata which form small tumors. When repair takes place, that portion of the ligament which is not involved in the gummatous growth is left comparatively intact. In the later stages, when the disease has fully developed, the swelling changes in character from being firm and hard to a softer consistence, and pseudo-fluctuation may be detected. The gummata may break down entirely at this stage, but under proper treatment they are usually absorbed. When the parts that have been destroyed are replaced by new tissue, the resulting scar

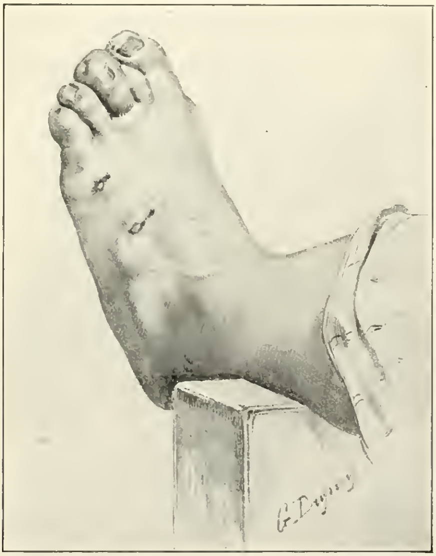

FIG. 174.—Syphilitic Dactylitis of the Middle Toe. (From report of Dr. A. P. C. Ashhurst, in the *Journal of the American Medical Association*, February 24th, 1906.)

formation sometimes binds the fingers more closely than normally and produces marked deformity. Involvement of the ligaments of the joints and the synovial membrane often results in impaired motion of the joint or even in complete ankylosis. This form of dactylitis occurs most often in the first phalangeal joint, and is generally accompanied by other lesions of syphilis.

In the second variety of dactylitis the change begins in either the periosteum or the bone. The gummatous involvement increases the size of the bone, and the soft parts are stretched and rendered tense. The skin becomes red and

is exceedingly tender. If the periosteum is first attacked it thickens and may separate from the bone. Small nodules are often formed, and these either break down or cause a permanent enlargement. When ostitis first occurs, the rarefying form is the one usually observed. The destruction caused by this form of ostitis is sometimes very marked, although it may be limited to the surface of the bone, and, later on, may be accompanied or followed in many instances by productive ostitis which gives rise to eburnation. When the tissues in this variety of dactylitis break down, the material gradually comes to the surface, and more or less destruction of the soft parts occurs. The size of the finger involved is ultimately either increased or diminished, the result depending upon the form of ostitis that predominates. Diminution in size, however, is the usual result, either the length or the thickness of the digit being changed. The joint may be entirely ankylosed, or its complete destruction may result in the formation of a false joint. Eburnation, when fully developed, forms very firm bone so that even when the tissues are decreased in size, the strength of the finger often remains unaltered. When the interior of the bone is invaded early, osteomyelitis results, and the disease then runs a more acute course and the increase in the size of the bone takes place more rapidly. When there is a great degree of swelling, ulceration is likely to occur, as in other forms of the disease, with discharge of the broken-down contents of the gumma, and often secondary infection and the formation of a chronic ulcer or sinus result.

As dactylitis affects the toes much more rarely than it does the fingers, the following case is quoted from Dr. A. P. C. Ashhurst, whose published report may be found in the *Journal of the American Medical Association* of February 24th, 1906:

Patient, male, aged 40 years, came under treatment of Dr. Ashhurst on April 20th, 1904, for disease of the left foot. Examination showed that the foot was moderately swollen, with two areas of superficial ulceration on the dorsum. The middle toe was the seat of typical syphilitic dactylitis. The patient stated that the ulceration had persisted in its present form for eighteen months, and that the toe had been swollen for about six months. He had tried various salves and ointments without avail. He gave a history of having had a sore on his penis twelve years previously, which sore, though accompanied by suppurating buboes, was followed by an eruption of the skin. Constitutional treatment was given for six weeks. The ulcers were dressed locally with dilute citrine ointment, and potassium iodide was administered internally. Improvement was rapid; the ulcers healed, and the dactylitis disappeared. Six months later the patient, who was then still taking potassium iodide, reported that his foot had given him no further trouble. It is probable, however, that when he stops taking the remedies the ulcers will recur. (Fig. 174.)

Dactylitis will respond to treatment with the same readiness as do other lesions of the tertiary or hereditary stage. The treatment should be both constitutional and local. The former consists of an exhibition of mercury and

potassium iodide, as suggested under the head of treatment of other syphilitic osseous lesions. It should always be borne in mind that personal hygiene, nourishing food, and tonics form an important part of the constitutional treatment in this stage of syphilis. The local treatment differs in no way from that of gummatous involvement of other bones. If mixed infection has occurred, the digit should be freely incised and treated according to general surgical principles. The incision should be so made as to avoid cutting nerves and tendons, and the fingers should be kept in that position which would be least inconvenient if ankylosis should occur. With this in view, extension must be maintained by the use of splints. In very rare instances amputation may be necessary. The majority of these cases, however, require nothing beyond constitutional treatment. When this is vigorously carried out, recovery by resolution and absorption is the rule.

DIAGNOSIS.

The diagnosis of syphilitic affections of the bone, whether acquired or hereditary, depends in a large measure upon the history of the case. Syphilis must always be borne in mind in any disease of the bone where the diagnosis is in doubt. It is well known that its primary and secondary stages may be so atypical or so mild as to render the diagnosis exceedingly difficult. This is particularly true in cases in which constitutional treatment has been administered during the primary stage. Under such circumstances it can never be definitely stated that the patient had a true chancre, for, as is well known, a lesion that appears to be typical is sometimes not a chancre, and *vice versa*. Not infrequently we find tertiary lesions (such as gummata of the liver or affections of the bone) that are so plain as to make the diagnosis of syphilis possible merely from the signs and symptoms that such neoplasms present, without any reference to the previous and oftentimes very vague history of syphilitic infection. The writer has seen three patients who had distinct gummata of the liver, but who had never manifested any secondary symptoms. They had, however, been subjected to rather vigorous treatment during the primary stage. The gummata developed about ten years after the primary stage.

The chief points relating to the diagnosis between syphilis of the bone and other osseous affections may be gathered from the following facts: The history of the case should be carefully inquired into, particular attention being paid to the history of chancre. Acquired syphilis of the bone begins most frequently in the periosteum and tends to the formation of new bone in the immediate neighborhood of the necrosis. Syphilitic inflammation of the bone is usually unaccompanied by suppuration, and does not often involve the neighboring joints. The frequency of the simultaneous occurrence of lesions

in various parts of the body, with a tendency to be symmetrical, is a very important point. Necrosis of the nasal or ethmoid bones, affecting the shape of the nose, always warrants a suspicion of syphilis. It more frequently changes the shaft of the long bones than the epiphysis, except in cases of hereditary syphilis, where the epiphyses are frequently involved. Osteocopic pains which are referred to the bone involved are in some cases characteristic, though too

FIG. 175.—Syphilitic Hyperostosis of the Tibia. *a*, Surface view, showing the eroded condition of the bone and the presence of osteophytes; *b*, section of the same bone, showing the obliteration of the medullary cavity. In the central portion there is osteosclerosis; above and below, there is osteoporosis. (Erich Lexer: "Lehrbuch der allgemeinen Chirurgie," 1904.)

much stress should not be laid upon this feature alone. The facts that the pain is worse at night, that it is usually continuous, and that it has a boring character are significant. The pain, in cases of a non-syphilitic nature, is more or less constant, is frequently very acute, and is often relieved, at least in some degree, by traction or fixation, which is not the case in syphilitic affections. The lesions in syphilitic diseases of the bone are often symmetrical. It is quite

common to find both tibiæ affected at the same time (Fig. 176); but, if the lesions are not symmetrical, other lesions either of other bones or of the soft tissues are likely to be present at the same time. A microscopical examination shows the histological character of the gumma, and, while this is not in any case entirely pathognomonic, the picture presented under the microscope is certainly sufficient to exclude either tuberculous disease or a malignant tumor. Thick-

Fig. 176.—Syphilitic Ostitis in a Man Thirty Years of Age. Note the sabre-blade deformity of the left leg. *A*, External view of affected limbs; *B*, *x*-ray picture of one limb. (Erich Lexer: "Lehrbuch der allgemeinen Chirurgie," 1904.)

ening of the blood-vessels must be particularly borne in mind in making microscopical examinations of the suspected syphilitic tissue. On account of inflammation of the periosteum, the bone is usually increased in size. Sometimes a localized isolated nodule exists. Marked increase of temperature is rare, as is also amyloid degeneration of the kidneys or liver, which is found after chronic pyogenic inflammations of the bone. General enlargement of

the lymph nodes is usually present. The shape and character of the long bone affected are very suggestive of syphilis; if it is bowed, covered with nodules, or possesses the hard and dense structure of eburnation, the diagnosis of syphilis is most probable. (Figs. 175 and 176.)

In cases of hereditary syphilis there is danger of mistaking the disease for rickets. In differentiating syphilitic disease from the latter, it must be remembered that hereditary syphilis differs from acquired syphilis chiefly in the fact that it is engrafted upon the fœtus and so exercises its baneful influences while the embryonal structures are developing and throughout early infancy. During this time the formation and growth of new tissues present conditions entirely different from those which obtain at the time when the acquired form of syphilis is contracted—that is, in the vast majority of cases, after puberty. In the differential diagnosis between hereditary syphilis and other diseases it will be sufficient to emphasize the points of difference between hereditary syphilis and the acquired form, as in the main the lesions would be similar. Affections of epiphyseal cartilages have a tendency to manifest themselves in the distal ends of long bones, and to produce, while development proceeds, nodes and sometimes rings of bone. Or gelatiniform degeneration may cause a separation of the epiphysis and thus produce a pseudo-paralysis. These things do not, for obvious reasons, occur in acquired syphilis in adults. The tendency of hereditary syphilis to affect the bones of the skull in early infant life has already been commented upon. After this time, however, hereditary syphilis does not attack the skull with the same frequency as the acquired form. Epiphyseal swellings in infants under six months are almost always syphilitic. The points mentioned, when considered in connection with the fact that the bending of the bones in rickets is quite different from the bending and thickening found in hereditary syphilis, will often suffice to differentiate between rickets and syphilis. The bowing of the tibia in the latter disease is pronounced, and assumes a characteristic sabre-blade appearance (Fig. 176), in which the foot is somewhat everted and flattened, while the lower portion of the shaft of the tibia curves forward and slightly inward. This bowing is always accompanied by decided thickening of the crest of the tibia, which is in marked contrast to the very sharp edges of the crest of the tibia in the bending that characterizes rickets. There is no particular kind of deformity that is typical of rickets. In some cases it may assume the shape that is characteristic of hereditary syphilis, although this is unusual, for the middle of the bone is more often curved in rickets than in the case of hereditary syphilis. The chief point, however, is the fact that in every case the bone is thickened in syphilis, particularly the crest of the tibia, whereas in rickets, whatever form the bending may take, it is always accompanied by a thin, sharp anterior border. In some cases this is so marked as to produce the impression that the skin might almost be cut through or destroyed by the sharp crest. In hereditary syphilis in infancy, the

bones of the skull ossify and the fontanelles tend to close much earlier than they would normally, whereas in rickets the bones are soft and the fontanelles remain open an unusually long time, while the head presents a peculiar box-like appearance not found in syphilis. The change in the shape of the skull due to the development of nodes—a feature that has been sufficiently emphasized by Parrot—has also been alluded to and must be borne in mind. It has been quite definitely proven that there is no connection between syphilis and rickets, and that they are two separate and distinct diseases; and yet Parrot, who has done such valuable and extensive work in the study of syphilis, earnestly contended that rickets was due to some form of hereditary syphilis. A close examination of this point by subsequent authorities demonstrated that Parrot was in error.

In all cases of syphilitic disease of the bone the effect of treatment is usually pronounced, and is one of the main points in diagnosis, although some cases that appear to be unquestionably syphilitic seem to be but slightly modified by antisyphilitic treatment. Frequently a temporary improvement follows the use of mercurials in some diseases that are not syphilis. Improvement under treatment, to be of diagnostic value, must be marked and sustained. It is not necessary that there should be an absolute cure, and, of course, deformities that have already occurred cannot always be remedied; but if antisyphilitic treatment produces an arrest of the progress of the disease and cessation of the osteocopic pains, together with diminution in size of the deposits and gummata, a diagnosis of syphilis can be positively made.

PROGNOSIS.

The prognosis of syphilitic diseases of bone depends upon many factors. In the acquired form it is often grave, but it is modified by the amount of treatment and by the patient's power of resistance and general constitution. Some patients, whose power of resistance is feeble, seem to withstand the inroads of any kind of disease very poorly, and in such instances the ravages of syphilis will be great. In other cases bone affections make but little impression upon the general health of the individual. The portion of the osseous system affected is necessarily of great importance in pronouncing a prognosis. For instance, if the skull is extensively involved, necrosis would be liable to result in meningitis, and the prognosis should then be much more serious than where only the bones of the leg are diseased. In like manner, involvement of the vertebræ, while rare, would occasion most serious symptoms if the spinal canal should be encroached upon to any marked extent. The damage to the spinal cord might be so great as to inflict a permanent injury upon it, even though the bony tumor should afterward disappear. In hereditary syphilis the mortality in early life is enormous. Some authors claim that, of infants born of syphilitic

mothers who have not been subjected to mercurial treatment, more than ninety per cent die before reaching childhood. If the mothers are put upon anti-syphilitic treatment the death rate is lessened very greatly. Late hereditary syphilis of the bone, developing in early adolescence or after maturity, is not so serious as when it appears in infants and in young children. While in most instances proper treatment will cause disappearance of the active syphilitic process, permanent enlargement of the bone, or permanent deformity of its contour, will frequently remain.

TREATMENT.

The most important indication in the treatment of syphilitic affections of the bones is the constitutional treatment. Syphilis of the bone occurs chiefly in the tertiary or hereditary form, but occasionally it is met with in the secondary stage and even in the primary. There need be no particular change from the ordinary treatment in these stages, on account of involvement of the bone. As is well known, mercury in some form is the sheet anchor in the early stages, and should not be neglected in the late. Potassium iodide is of the greater efficacy in the tertiary and in the hereditary forms, although there are some cases of syphilis of the bone that are apparently unaffected by either the iodides or the mercurials. In regard to such cases it must be borne in mind that these lesions are often the result of previous syphilitic invasion, and that necrosis of the bone is more likely to be due to secondary infection with pus germs than to syphilitic virus. In cases like these the previous weakening of the patient's constitution, together with the presence of pathological bone, will present a very suitable field for invasion by pyogenic germs. Here treatment must follow ordinary surgical lines, and necrosed bone be removed by rongeur forceps, the curette, or the chisel—just as after any other inflammation of the bone. For ordinary cases, particularly if the disease develops early, mercurials are best administered in the form of the protiodide of mercury, beginning with the eighth of a grain an hour after meals, and increasing the dose gradually each day, until the point of toleration has been reached. The advantage of this form of treatment is that colicky diarrhœa is established before salivation, whereas salivation is apt to be the first symptom where other mercurials are given. In the late stages of the disease, or in patients whose stomachs will not tolerate mercury, inunctions are valuable. They are best given for four consecutive days, the body being divided into four portions into each of which the mercury is thoroughly rubbed on one of these four days. On the fifth day a bath can be given, and on the sixth day the procedure repeated for another period of four days. The best ointment is one prepared from the following formula: Compound tincture of benzoin, ʒ ss.; mercury and lanolin, each ℥ i. A drachm of this is to be used daily.

Mixed treatment is rarely indicated. It is better to give mercury for a while and then potassium iodide alone or in any simple menstruum such as compound syrup of sarsaparilla. It is difficult to state the dose of the iodide, as some patients can take a great deal more than others. The effectiveness and rapidity of the cure depend in a large measure upon the amount of iodide a patient can take. It may be administered at the same time that inunctions are given, although this is not often necessary. It is well to commence with five grains three times a day, given an hour after meals, and well diluted in water. This dose may be increased three grains each day until the patient shows signs of intolerance, or until there is marked evidence that the disease is being checked. As much as an ounce a day has been give for weeks at a time without any untoward effects. Too often a cure is prevented by following the strict dosage as laid down in the text-books. If properly increased the dose may be pushed to any limit short of the exhibition of marked intolerance. Hot baths, by hastening the elimination of these drugs through the skin, and proper clothing to prevent chilling of the skin, render it possible to increase the amount of the iodides and mercurials that can be administered in any given case. The patient's constitution must be borne in mind, and tonics, such as iron and strychnine, should be given when indicated. Proper ventilation of the sleeping apartments, nutritious and wholesome diet, and moderate exercise are always necessary, and it is as much the duty of the surgeon to look into these matters, and to regulate them properly, as it is to give mercurials or iodides.

For cases where neither marked necrosis nor ulceration exists there is no indication for local treatment. Local treatment, when necessary, consists of the same surgical measures that would be indicated in any inflammatory condition of the bone when necrosis has developed, or when pyogenic infections occur in the syphilitic lesions. The patient who is well nourished and well treated will stand an operation in a satisfactory manner and should not be denied the benefits of one when there is an indication that such operative interference is needed. Fractures caused by weakening and thinning of the bone from gummata usually unite promptly when dealt with according to the ordinary surgical methods for fractures, and when the patient is given antisyphilitic treatment at the same time. When the epiphysis has separated from the shaft of the bone, a splint should be applied as in the case of a fracture. If the pain is severe in a long bone, an incision through the periosteum frequently gives relief. If a sequestrum is present it will separate more slowly than would be the case after simple pyogenic infections; for this reason, therefore, an operation should be performed earlier than after the latter disease. When the bone affection or the exostosis seems to prove a source of serious irritation or produces pressure upon nerves and contiguous vessels, an operation should be performed much earlier than where such important structures are not liable to injury.

TUMORS ORIGINATING IN BONE.

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OSTEOMA.

An osteoma is a tumor composed entirely of bone tissue. This definition should be strictly adhered to, and in this class should not be included, as is often done, tumors in which bone formation is a secondary process, as the formation of true bone may occur in nearly all tumors both of the soft parts and of the skeleton. To tumors of this character the adjective ossificans should be applied. The term is also often used in a restricted sense, clinically, for the purpose of designating one form of osteoma, namely, the osteoma eburneum, and not in its proper sense for the entire group of bony new-growths.

Owing to the manner in which the various names of the tumors of bone have been applied, osteomata have been classified in different ways by clinicians and pathologists. They are best divided, from a scientific standpoint, into three main groups: (1) hyperplastic bone tumors; (2) heteroplastic bone tumors; (3) true bone tumors.

Under the term hyperplasias should be classed the inflammatory new-growths of bone consisting of the osteophytes and the hyperostoses.

The heteroplastic bone tumors arise from a pre-existing *Anlage*, as from foci in the periosteum or from displaced bits of cartilage; and there is some question as to whether tumors belonging to this form should not be classed as ossifying chondromata.

True bone tumors constitute a very small group and may be defined as genuine autonomous bony growths arising as such from the bone and showing an independent and progressive growth (Borst *). That such tumors exist is unquestioned, but they must be extremely rare.

Tumors belonging to all of these groups present many different forms, and, although theoretically the foregoing classification is correct, it is in many cases impossible to determine whether a given tumor is heteroplastic or a true bone tumor. In many other cases, however, the origin is very evident.

All of these bony growths present themselves in various shapes, as flat, tuberous, branching, lobulated, or pointed growths of all sizes, and they cannot be described in a few words. They also may be seen on any bone in the body, although certain bones are more frequently affected by certain forms of tumors. McGavin's table of the position of the osteoma, in the eighty-two cases observed

* "Die Lehre von den Geschwülsten," 1902.

at Guy's Hospital during a period of two years, gives an idea of the relative frequency with which certain bones are affected, although no attempt is made to classify them as to their origin.

McGavin's Table.

Subungual	26	Radius, lower end	1
Femur, lower end	18	Metacarpal	1
" upper "	1	Auditory canal	1
Tibia, lower end	1	Cervical vertebra	1
" upper "	8	Calvarium	4
" shaft	1	"Orbit"	3
Humerus, upper end	4	Scapula	2
" lower "	1	Leontiasis	1
Fibula, upper end	1	Multiple	6
" lower "	1		

The tumors may be in any relation to the bone—viz., in the interior (endostoma), on it, beside it (parostoma), or situated in the soft parts at varying distances from the bone and having no relation to it.

The tumors are also often classified, according to their mode of origin, into three groups: fibrous, from the periosteum; cartilaginous, from a pre-existing displaced bit of cartilage; and those originating from the medullary substance of the bone. This last class comprises a very small group of tumors.

Histologically, aside from the cartilaginous exostoses which will be described later, two main types of growths are recognized: the spongy and the eburneous forms. The histology of the spongy exostosis is indentical with that of normal bone. Delicate, branching, bony trabeculæ are seen separating marrow spaces which may contain either red or yellow bone marrow and through which thin-walled blood-vessels pass. These growths are usually covered on the outer side by a layer of denser cortical bone of varying thickness (medullary osteoma). This, in turn, is covered by periosteum, except in the case of enostoses, and may show foramina for the entrance of nutrient vessels. Eburneous osteoma (ivory osteoma, osteoma durum), on the other hand, is composed of extremely hard bone, which, on macroscopic section, has the appearance of ivory. All these bone tumors have a central medullary cavity containing red bone marrow, which in many cases can easily be overlooked. Microscopically, they present dense, bony trabeculæ separated by fine canals, the central medullary cavity having the appearance of normal bone.

Osteomata are in themselves all essentially benign and do not tend to recur or to form metastases. When a recurrence takes place, which it does chiefly in the cartilaginous form, it suggests incomplete removal. Recurrence following an inflammatory osteoma suggests that the cause has not been thoroughly eradicated.

Although, from a scientific standpoint, the classification above mentioned is the one to be preferred, it is better clinically to employ the terms commonly

used for designating the various types, and we shall employ them hereafter in the discussion of these tumors.

Types of Osteoma.

Osteophytes.—The term osteophyte is applied to flat or rounded small bony growths that arise in the periosteum and spread laterally, as the result of inflammatory conditions. They are not true tumors, but come rather under the head of hyperplasias; and clinically they are not in themselves of great interest, as they cause, as a rule, little inconvenience, are secondary to other diseases, and are best considered with those affections. They may be seen in any bone of the body, but, when associated with certain diseases, they are more frequently seen in definite locations. Thus, for example, in syphilis, osteophytes of the skull are recognized as characteristic lesions. In this locality they arise usually under the external periosteum, but they are also seen in the cranial cavity, arising from the inner layer of the dura, especially in the neighborhood of the frontal or occipital bone; in which case they may, through pressure, cause epilepsy or other brain symptoms.

In the long bones, osteophytes are most commonly seen in connection with tuberculous disease, in which two forms may be recognized: one, in the immediate neighborhood of the process, due to the inflammatory reaction; and a second, where the tumors are seen on healthy bone at some distance from the seat of the process, and are supposed to be due to the toxin of tuberculosis (Maillard) (*Ostéoarthropathie hypertrophiante pneumique*). They are also seen about bones in which inflammatory processes other than tuberculosis are taking place, and probably the most common form is that seen about the joints in the various forms of arthritis. Osteomyelitis is another condition in which the presence of osteophytes is often noticed.

Microscopically, osteophytes appear as delicate, branching trabeculæ or sheaves consisting of true bone or osteoid tissue, through which run many marrow spaces filled with very cellular connective tissue in which are large numbers of thin-walled blood-vessels. On the outer surface there is usually a thin layer of denser cortical bone. They belong, therefore, to the class of spongy or medullary growths.

From a clinical point of view, osteophytes are of comparatively little interest. With the exception of those which develop in the various forms of arthritis they rarely cause symptoms, and, as a rule, require no treatment. When they occur on the inner surface of the skull and cause symptoms which do not yield under antisyphilitic treatment, trephining may be done. Such operative interference, however, is applicable only in the case of growths located at the vertex, the presence of which can be located by the aid of the symptoms and the x-ray. If they are in the neighborhood of a joint and limit the normal motion

they may be cut down upon and removed with a chisel or gouge; but they are liable to recur.

Hyperostoses.—Hyperostoses may be defined as circumscribed or diffuse new-formations of bone arising either from the periosteum or from the spongy part of the bone (Borst). Although certain well-defined conditions come under this heading it is impossible to draw a distinct line between these forms of bony new-growths and the osteophytes on the one hand and the exostoses on the other. They may be encountered in any bone, but are more particularly associated with inflammatory conditions, and, therefore, come under the general heading of hyperplasias. One form is seen around osteomyelitic cavities, where, owing to a diffuse thickening of the spongy bone in association with a necrosis of the marrow cavities, hard, new bone is formed (osteosclerosis).

The process is seen locally in the external auditory meatus, where the diffuse

Fig. 177.—Diffuse New Bone Formation Following Fracture. (Warren Museum, Harvard Medical School.)

thickening of the bone causes narrowing of the canal and at times completely obliterates it.

Another form is seen in the alveolar processes, where it occurs either as a diffuse or as a localized swelling. As a rule, a small portion only of the alveolar process is affected, although occasionally the whole process may be enlarged.

In some cases diffuse, extensive endosteal and periosteal new-formation of bone, occurring independently of any demonstrable focus of inflammation, causes marked general deformity (diffuse general hyperostosis; Paget's disease; acromegaly). Another form that might be termed a diffuse hyperostosis is represented by the complete ossification of an exuberant callus, such as sometimes occurs after fracture (Fig. 177).

One form of hyperostosis which is classed under the heading of bone tumors is of especial interest, namely, leontiasis ossea.

Leontiasis Ossea.—Synonyms: partial gigantism, craniosclerosis, diffuse osteoma. This is a slowly progressive disease characterized by a diffuse hyper-

ostosis of the bones of the head, affecting mainly the vault of the cranium, the upper and lower jaws, and certain bones of the face; these alterations being associated with ill-defined constitutional symptoms.

The disease has long been known and was described more or less accurately by many men in the early part of the century, although in some cases it was evidently confused with acromegaly; but it was not until Virchow described it that its existence was established on a firm basis. Subsequently, in 1892, Baumgarten collected thirteen cases from museums of Europe, and Putnam* reported five cases in 1896. Several other isolated cases have been reported.

The name leontiasis ossea was given the disease by Virchow on account of the leonine appearance of the face and its similarity to a certain form of tubercular leprosy. It is probably not as uncommon as the few reported cases would lead one to suppose, it being often overlooked or confused with other conditions. Schuchardt † mentions ten completely reported cases, many of those previously reported by Baumgarten being without clinical data.

The predisposing causes are not well known, the disease having an insidious onset usually about the period of puberty. In many cases it has been preceded by inflammation of some of the neighboring parts, which inflammation is commonly given as a prominent etiological factor. In Forcade's case, the onset of the disease followed an inflammation of the tear duct in a boy of twelve. Schuchardt mentions swelling of the cervical lymph nodes as often preceding the onset of the disease. Virchow was the originator of the inflammatory theory, and believed the disease to be a purely local inflammatory process. The main support of this theory is the appearance of the bones, the condition of which strongly suggests inflammatory changes such as those observed in syphilis. Virchow, however, speaks of heredity as possibly having some influence, the condition of the bone only representing a local manifestation of a general condition.

The possibility that the changes in the bone represent a trophic disease was first suggested by Baumgarten. In some of his cases the sella turcica was enlarged, and Starr mentions the similarity between this enlargement and certain other of the trophic disturbances, as myxœdema, Addison's disease, and acromegaly, but does not suggest the gland to which it bears relation. Bassoe has reported the case of a patient who was evidently suffering from leontiasis which was complicated by gigantism and acromegaly. In the present state of our knowledge, however, it is impossibe to say whether leontiasis should be put with this class of diseases or considered as a purely local inflammatory process.

Tuberculosis has no relation to it, nor has syphilis, and yet the appearances are similar to those observed in the tertiary or congenital form of the latter disease, the bones of the cranium being hard and ivory-like. Rickets has been

* American Journal Medical Sciences, 1896, cxii. † Deutsche Chirurgie, 1899, xxiii.

suggested as a possible cause, and in certain cases there may be some such relationship. Acromegaly has nothing in common with it, for in this disease the bones of the hands are first affected, and the changes in the head involve chiefly the bones of the face and are of the nature of a hypertrophy, not of an inflammatory condition such as exists in leontiasis.

In certain of the cases (Prince, Buhl, Priestley) trauma preceded the bony changes, but in most instances it could have played only an insignificant part.

In typical cases the onset of leontiasis occurs insidiously before the period of puberty, but the disease is also seen in older people, and some of those affected have shown no symptoms until they were nearly fifty years of age. Both sexes are equally affected.

Pathology.—Pathologically, leontiasis has been termed a hypertrophy, a form of new-growth, and an ostitis, but at present it certainly cannot be regarded as either of the first two of these, and there is some question as to whether it is an ostitis, although the changes are strictly of an inflammatory character. The process begins usually in the upper jaw near the nasal spine, more commonly on the right side, but it soon becomes symmetrical, although it may start in the frontal bone, or, rarely, in the lower jaw. Later, as the disease progresses, all the bones of the face, as well as those of the cranium, are involved to a greater or less extent, the anterior portion showing usually the most change.

In the advanced cases the bones are all thickened, and those of the face are distorted, showing hyperostoses and eroded surfaces as the result of periostitis. The skull, on account of this thickening, is much increased in weight, the dried specimen often weighing five kilogrammes, or five times as much as the normal. The appearance of the bone is that which results from an ostitis, and the skulls in this respect somewhat resemble those observed in hereditary syphilis. In the vertex, where the process can be best studied, the bone is often four centimetres in thickness. This new formation of bone takes place on both the inner and the outer tables, with a corresponding increase in the girth of the head and a diminution in size of the brain cavity, into which, at times, small hyperostoses project. The bone is of almost ivory-like hardness, and the diploë is usually obliterated, the growth, therefore, being both an exostosis and an enostosis. In acromegaly and hypertrophic conditions, on the other hand, the relation of the diploë to the cortical bone is approximately normal, and the cortical bone is of normal consistence. At the base of the skull the changes are, as a rule, very slightly marked, and it is a fact that the foramina are usually of normal diameter in spite of the thickened bone. The sella turcica in some cases has been narrowed, while in others it is somewhat increased in size.

In the upper jaw the pathological process appears as a diffuse thickening of the entire bone, in the form of enostoses and exostoses and occasionally as tuberous prominences, the latter being seen near the nasal spine, where the process commonly begins, or over the malar bone. This increase

in the size of the bone may fill up the antrum or block the nasal cavity, in which case necrosis and changes due to secondary infections are commonly seen. If the hard palate is involved, it may be pushed down into the mouth to the level of the borders of the alveolar process, and involvement of the latter is associated with a loss of the teeth. Growth into the orbit of either the superior maxilla, the frontal bone, or the sphenoid causes a narrowing of that cavity, forcing the eye out. In the frontal bone there is often an associated inflammation of the sinus.

The other bones of the body are perfectly normal, and changes of the soft parts, except those secondary to pressure and sepsis, are practically unknown. Starr, however, mentions a case in which there was some extension of the process to the two upper vertebræ.

Symptoms and Course.—Baumgarten divides the symptoms arbitrarily into three classes according to whether the upper jaw, frontal bone, or lower jaw is primarily involved, but the final picture in all of these forms is about the same. The disease begins insidiously in persons in previously good health; usually in children the first change noticed being the tumor of the spine of the superior maxilla and a flattening of the nose at the base due to some thickening of the nasal bones. From this the growth continues slowly and symmetrically, involving the frontal bone, vertex, and lower jaw. Plugging of the nasal cavity results in loss of smell and in mouth-breathing, which latter symptom is probably of more common occurrence than is usually supposed; involvement of the antrum may occur early. The pressure of the hard palate into the mouth, and the loss of the teeth in cases where the alveolar process is involved, cause some difficulty in deglutition, as well as loss of taste. The malar bone is prominent. Encroachment of the bone on the orbit forces the eye out, and the exophthalmus may be so marked that the lids do not cover the cornea. When this occurs, ulcers are likely to form, with subsequent panophthalmitis and blindness. Optic neuritis, due to lengthening of the nerve, to pressure from narrowing of the sphenoidal sinuses, or to intracranial pressure, is also sometimes observed.

If the disease begins in the frontal bone one of the first signs is a protruding forehead, often complicated by inflammation of the sinus. When starting in the lower jaw leontiasis is characterized by irregular hyperostosis, but wherever it begins the process soon becomes general.

The involvement of the skull is characterized by its constantly increasing size and by a bulging forehead, both of which changes give to the head a hydrocephalic appearance. Epilepsy from pressure is observed at times, either as an early or as a late symptom, and its presence may denote a hyperostosis from the inner table. Headache is a prominent symptom and is present in more than half the cases, being due in greater part to pain in the bones and not to pressure on the brain. Deafness and vertigo are also at times noted. Pressure on the brain may cause not only epilepsy, but also blindness, vertigo, deafness,

tinnitus aurium, peripheral paralysis of the cranial nerves, and other symptoms of brain tumor. Later, there are diminished mentality, or dementia, and slow awkward movements of the extremities. In the last years the patient presents a much deformed and distorted large head, with prominent cheek bones, bulging forehead, and exophthalmus, placed on a normal body.

Diagnosis.—The diagnosis in the early stages is difficult and cannot usually be made until the disease is well advanced, when the symmetry of the growths, the prominent forehead, and the signs of involvement of the orbit, nares, and sinuses serve to differentiate it from other forms of tumors. It is most easily confounded with sarcoma, but can be differentiated from it by its slow growth and by the signs of involvement of more than one bone. Paget's disease and von Recklinghausen's disease occur later in life, affect primarily the long bones, and are accompanied by pain, which symptom is absent in leontiasis. In acromegaly the lower jaw and the bones of the face are involved, as are also those of the hands, where the process usually starts. Acromegaly also is generally seen in later life.

Prognosis.—The disease is always fatal, but it runs a slow course (from twenty to forty years), with a gradual increase in the symptoms; occasionally these may be temporarily arrested, but there is never retrogression. An attack of erysipelas may materially hasten the course, and the patient eventually dies of this or some other intercurrent disease, or of dementia.

Treatment.—No treatment is of any avail, the disease being unaffected by any remedy. Thyroid and other gland extracts have been used, on the theory that the disease is a trophic disturbance, but without avail. In cases where the disease is recognized early and where it is confined to one jaw, excision has been done to relieve such symptoms as pressure on the eye and nose. To this extent the operation has been measurably successful, but it is doubtful whether it has produced any effect on the course of the disease (Bland-Sutton).

Exostoses.—An exostosis is a circumscribed bony growth projecting from the surface of a bone. It will be seen from the definition, as has already been stated, that no distinct line can be drawn between this form of new-growth and certain of the foregoing. Exostoses may be of any form—flat, tuberous, conical, or branching; and of any character—spongy, eburneous, etc. They may also occur in any bone, although certain forms have a predilection for certain bones. Thus, for example, the epiphyseal ends of the long bones are the common seats of the spongy exostoses (Fig. 178), while the eburneous outgrowths are usually seen in relation to the skull.

In general, they may be divided into two main classes: the fibrous or periosteal, which arise from the periosteum (or adjacent tissues); and the cartilaginous, which originate, as the name implies, from displaced bits of cartilage.

The *fibrous exostoses* arise either from the inner surface of the periosteum (in which case they are connected with the bone from the beginning) or from

the middle layer, becoming attached to the bone later (disconnected exostoses). In still other cases the new-growth begins with ossification in a tendon or aponeurosis, and then soon afterward becomes attached to the bone.

The cause is in any case obscure, but in a large proportion inflammation is an important factor. Exostoses often come after trauma—as, for example, after

Fig. 178.—Spongy Exostosis of the Lower Part of the Fibula. (Original.)

a fracture—or they appear near the seat of a diseased bone. In this connection may be mentioned the ossification observed in the deltoid, in the adductors, and in the quadratus femoris; such osseous growths, however, do not come under the heading of true exostoses.

The most common seat of eburneous exostoses is the skull. They arise on the vertex at any point; indeed, all the bones of the skull have been reported as having been the seats of such growths. They are either flat, sessile tumors, slightly raised, or they are cone-shaped, with a broad base. Sometimes they

are even tuberous, with more or less of a pedicle. They vary in size as well as in shape, in time attaining large dimensions, but they are of very slow growth. Most of them arise from the external periosteum, but they occasionally start in the diploë (enostoses) or even from the inner layer of the dura, inside the skull. Sex and age have no influence on the growths, although they occur

FIG. 179.—Multiple Cartilaginous Exostoses of the Femur and Tibia. Four members of the family have the disease. (Massachusetts General Hospital.)

more commonly in the male. Trauma has a distinct bearing on the etiology of these growths.

Symptoms.—Exostoses, when external, cause no symptoms except such as are of a mechanical nature. If they extend into the cranial cavity symptoms of brain irritation may be present.

Diagnosis.—The diagnosis is usually perfectly simple. In cases in which there is a question of sarcoma an x-ray examination will show the character of the tumor and will also be found of value in determining whether the brain

cavity is involved, and the dimensions of the base of the growth. It is necessary in these cases to exclude syphilis, tuberculosis, and allied conditions.

The *prognosis*, as regards life, is good provided the growth be external, as it is essentially a benign tumor: when, however, there is compression of the brain, the prognosis depends on the size of the growth and its location.

Treatment.—No treatment other than operative is of avail. The tumor should be completely exposed. If it is sessile and eburneous it is useless to attempt removal with a chisel or gouge, as the bone is so hard that it will turn the edge of almost any instrument. If, however, it is pedunculated, the pedicle can often be sawed. When the outer table only is involved it may be removed with the growth, but in most cases it is necessary to cut through the skull with a trephine, dental engine, or similar bone instrument, and remove the growth in its entirety with a portion of the vertex.

Regions Where "Fibrous Exostoses" are Especially Apt to Occur.

Ear.—Exostoses of the auditory canal are not uncommon and are seen either in the form of a mass of ivory-like hardness or in that of a spongy bone tissue, conical or tuberous in shape. They are often pedunculated and may be removed with a hammer and chisel. A diffuse hyperostosis and a cartilaginous exostosis are conditions which are also observed in this locality.

Orbit.—Osteomata of the orbit are rare tumors and are either eburneous or spongy. The term "orbital osteoma" is commonly employed to designate those tumors which originate in the sinuses and invade the orbit secondarily.

Jaws.—Spongy, symmetrical osteomata of the nasal process of the upper jaw are observed at times. Such growths appear in the form of a somewhat diffuse, oval swelling at the internal canthus, usually about puberty; and they can be removed with a hammer and chisel. (Exostoses in this locality are more common in negroes.)

Next to the skull, the lower jaw is most commonly the seat of the ivory-like exostosis; and, so far as the treatment is concerned, the same rules apply as in the case of exostoses of the skull. The prognosis is better here than in the skull, as there are fewer important structures in the neighborhood.

Ivory-like and spongy exostoses of the alveolar process are sometimes observed; they are usually diffuse. If localized, and if they interfere with deglutition or cause deformity, a portion of the alveolar process may be removed.

Flat Bones.—Fibrous osteomata of the flat bones occur in a great variety of shapes, but they are comparatively rare. There have also been reported cases in which the bony new-growths have developed from various portions of the vertebral column, and have caused paralysis and death through pressure upon the cord. Most of these, however, are of cartilaginous origin.

On the *long bones* they arise commonly as a result of trauma and are com-

paratively rare. (Fig. 179.) There is one form of traumatic exostosis which occurs in the long bones and develops rather rapidly (in from one to four weeks). It is commonly observed on the tibia, where it manifests itself as a tender swelling which increases rapidly until it reaches a considerable size. After a time, however, it ceases to grow. It is almost impossible to differentiate it from some form of periosteal sarcoma except by microscopic examination and by the fact that it does remain stationary after reaching a certain size. Removal with mallet and chisel may be practised; but if the growth is removed at an early stage it is

Fig. 180.—Endostoma of the Ulna and probably of the Lower End of the Humerus. The specimen was composed of rather dense cancellated bone. (Original.)

very apt to recur. When it is seen late, no treatment is indicated. Schuler * has reported five of these cases in detail.

When the tumor is examined with the x-ray the appearance is that of a hard, bony new-growth of the periosteum, simulating somewhat the appearance of a syphilitic lesion.

Insertions of Muscles.—The tendinous or aponeurotic forms of exostoses arise from ossification at the insertions of the muscles. They are seen as flat, thin plates of bone when in an aponeurosis, and conical if in a tendon. The aponeurosis of the adductor magnus at its attachment to the linea aspera, its tendon where it is joined to the adductor tubercle, and the tendon of the gastrocnemius at its point of insertion into the os calcis, are the most common seats, although any muscle or tendon may be involved. The diagnosis is easily made by the x-ray, and the growth may be removed by the usual methods.

Endostoma.—Endostoma is the name applied to bony tumors arising in the

* Beitr. z. klin. Chir., 1902, xxxiii., 556.

centre of a bone. The condition was first described by Virchow, and since then but few cases have been reported, the condition being very rare. Benneke* reported a case in 1904 and at that time could find only one other in the literature, a case of Landow's. In the reported cases, the tumor arises from the bone marrow at the head of the bone, and grows slowly, forming normal but compact, spongy bone. In the growth of the tumor the surrounding trabeculæ are absorbed, and the head of the bone becomes gradually distended by the new-growth. With the x-ray the tumors are seen as distinct shadows surrounded by the normal bone, and when large they show the structure commonly seen in spongy bone (Fig. 180). In Landow's case the new-growth arose in the humerus, and he was able to demonstrate it as originating from an invagination of the periosteum. The symptoms are: excessive pain, continuing for some time and referred to the head of the bone; and, at a later stage, a more or less symmetrical enlargement and some interference with the function. From the meagre data at hand, however, it is impossible to generalize to any extent.

Diagnosis.—Clinically, the diagnosis cannot be made. With the aid of the x-ray it is possible to distinguish the presence of a tumor somewhat denser than normal bone, but having otherwise all the characteristics of such bone; and if it be situated in the end of a bone it may be suspected of being an endostoma. At the same time it may be impossible to rule out sarcoma or cyst.

Prognosis.—The tumors are benign and do not recur after removal.

Treatment.—The treatment is, removal. The bone should be cut down upon and removed with a hammer and chisel until the tumor is completely exposed, when it can be shelled out. The hemorrhage then having been controlled, the edges of the wound in the skin should be approximated, but not sutured tightly, as it is better to let the serum drain out for a short time; or the cavity may be packed and allowed to heal by granulation.

Cartilaginous Exostoses.—Cartilaginous exostoses are those bony tumors which arise by the growth and calcification of pre-existing islands of cartilage. They are either single or multiple and form by far the most important class of exostoses. Single cartilaginous exostoses arise either by a faulty lateral growth of the epiphyseal cartilage, in which case they are connected with it, or they arise in the diaphysis, usually in close proximity to the epiphyseal line. Their origin in the latter case is from islands of the transitory cartilage cut off in the process of growth of the bone. That this occurs has been conclusively shown by Virchow, and the fact explains the rare cases in which this form of exostosis is seen near the centre of the diaphysis. Cartilaginous exostoses are encountered most commonly in the long bones, the upper end of the tibia being the seat of predilection (Fig. 181). Next to this, the lower end of the femur is the most common seat; and then follow, in the order in which they are found to be affected, the other long bones, with

* Deut. med. Wochenschr., 1904, xxx., 941.

the exception of those of the hand and foot, where these exostoses rarely occur. They are also seen on the pelvis, on the scapulæ, and rarely on the head, vertebræ, and sternum.

Cartilaginous exostoses occur in the first two decades of life, that is, during the period of active bony growth, and it is an extremely rare occurrence for them to arise after the twentieth year. If they develop previously to this they cease growing with the complete formation of the skeleton. Sex has no influence,

FIG. 181.—Cartilaginous Exostosis of the Head of the Tibia. (Massachusetts General Hospital.)

and the questions of heredity and rachitis do not have as important a place in the etiology as is the case in the multiple form, but every grade between the single and the advanced multiple type may be seen.

Pathology.—In gross, the tumors appear as irregular, usually long, rounded outgrowths, varying in size, with pointed, tuberous, or mushroom-shaped heads. They may, however, be of any shape, are often branching, and generally do not extend at right angles to the bone, but grow backward over the shaft.

They are often covered by a bursa containing more or less fluid and at times

filled with irregular free cartilaginous bodies (exostosis bursata). Histologically, they are composed of normal spongy bone covered with a denser layer of cortical bone and tipped with hyaline cartilage, from which they grow, bone being formed as in the normal epiphysis.

Symptoms.—The tumors cause no symptoms other than those due to pressure on the neighboring nerve trunks and the mechanical disability due to their interference with the action of the muscles and the limitation of movement in the adjacent joint. When in positions exposed to trauma they may become inflamed, and fracture is not uncommon. In the pelvis they usually arise from near the sacro-iliac synchondrosis, and owing to their position they remain unrecognized for some time. In this situation they may cause urinary symptoms and constipation, and in the female they may interfere materially with normal labor unless discovered previously and removed. When they are located outside the pelvic cavity, their significance is less grave and they may be easily removed. There have been reported extremely rare cases in which the exostoses were found to spring from the bodies of the vertebræ or from the basilar process of the occipital bone; paralysis and death having been caused by the pressure of the new-growth on the cord.

Although the ends of the long bones are the common seats of such cartilaginous exostoses they are seen in many other places which deserve special mention. They often occur, for example, as small conical growths in the external auditory meatus, where they may interfere materially with hearing. Others are seen as hard, somewhat eburneous tumors, rounded in shape and partly covered with cartilage, in the mastoid cells.

Diagnosis.—The diagnosis is usually easy to make, and, in the long bones at least, the appearances presented in the radiograph are characteristic. (Fig. 179.) In the pelvis it is impossible in many cases to differentiate them, by rectal or vaginal examination, from other hard tumors—sarcoma and chondroma—originating in the same position. The *x*-ray here will usually determine the diagnosis.

The *prognosis* is good, but it depends in large measure on the position of the tumor. The growths are benign and they usually cease to grow when the patient reaches adult age. When the tumor is situated in the pelvis or spinal canal the prognosis is not so good.

Treatment.—The proper treatment is removal, which can easily be accomplished. The tumor is exposed by an incision and its base cut through with a chisel, care being taken to remove all the cartilage. It is also best in most cases to remove with the growth a small portion of the normal cortical bone. When these tumors are located in the pelvis they are more difficult to remove. Zeller has collected three cases of operation for exostoses in this locality, with one death (Henking, 1878). They may be approached either abdominally or through the perineum. Kramer removed one in a pregnant woman by the

latter route, and the patient later had a normal delivery. The choice of the route depends naturally on the seat of the tumor.

Subungual Exostoses.—Probably the most common form of cartilaginous exostosis is the subungual variety, which occurs usually under the nail of the great toe; but there is some difference of opinion as to whether they are cartilaginous or periosteal. Of the many reported cases the majority appear undoubtedly to have arisen from the epiphyseal cartilage; and in support of this view is the fact that they are generally seen during adolescence, the time when cartilaginous exostoses usually occur. Virchow and many other observers maintain that they are fibrous, and in support of this view are the facts that they are rarely seen in cases of multiple cartilaginous exostoses, and are often separated from the bone proper by a layer of periosteum. Probably both forms occur, the cartilaginous, however, being the more common.

The predisposing cause is unknown, although there is often a distinct history of trauma. Both sexes are equally affected, the tumor usually appearing about the age of puberty, although it may be seen in people of advanced years. The great toe is, as a rule, the part affected, but one of the other toes or even a finger may be the seat of the growth.

Pathology.—The tumor is small, rarely exceeding one-half or three-quarters of an inch in diameter, and of slow growth. On transverse section it is found to be composed of spongy bone continuous with, and not to be distinguished from, the normal phalanx. This growth is covered with a layer of cartilage of varying thickness, and over all a thin fibrous layer is usually to be distinguished, this layer representing in some instances periosteum, but in most cases being derived from the adjacent tissues (Fig. 182). The skin covering the whole may be thickened, but, on account of pressure, particularly if the growth has reached a considerable size, it is apt to be ulcerated and necrotic. In some cases the tumors are separated from the phalanx by a thin layer of periosteum, and in these cases it is evident that the growth has developed in that membrane. There have also been reported cases in which the tumor contained many small islands of cartilage as well as the covering layer. Microscopically, they do not differ from other cartilaginous exostoses.

Symptoms.—The exostosis begins as a small painless swelling under the great-toe nail, usually being situated in the median line or slightly to the inner side. The tumor grows slowly and painlessly for a time, gradually displacing the nail and projecting from under its edge. As it increases in size it becomes more sensitive, until finally the slightest pressure causes acute pain, and the skin becomes ulcerated from pressure, with the resulting inflammatory changes in the surrounding parts. After attaining the size of about three-quarters of an inch in diameter the tumor ceases to grow.

Diagnosis.—The presence of a slowly growing hard tumor under the nail

of the great toe is sufficient for a diagnosis, but, if there is any doubt, an x-ray examination may be made, which, in the case of an exostosis, will show the presence of a bony growth. Sarcoma in this region is practically unknown, and chondroma is also rare and may be excluded by the x-ray.

Prognosis.—When not removed by an operation, the tumor will cease growing after reaching a certain size, but will cause more or less inconvenience during the patient's life. If operated upon, the growth shows no tendency to recur.

Treatment.—Palliative measures are useless. The nail should be extracted and the growth cut down upon and thoroughly removed with a gouge or bone forceps. In a few cases it will be found necessary to excise the terminal phalanx,

Fig. 182.—Photomicrograph of the Growing Surface of a Subungual (Chondral) Exostosis. (Original.) *a*, Fibrous tissue; *b*, cartilage cells in columns forming bone; *c*, newly formed bone.

and in others it is best to destroy the matrix of the nail on account of the deformity that is sure to occur if it is allowed to grow again.

Exostoses of the Accessory Sinuses.—The accessory sinuses of the nose are the commonest seats of the eburneous osteomata. They are usually seen in the frontal sinuses, but arise also in the antrum, ethmoid cells, and sphenoidal sinus. In 49 cases, 23 were of frontal origin and 11 ethmoidal, while 10 arose in the antrum and 5 in the sphenoidal sinus (Bornhaupt*). They are also occasionally seen in the nasal cavity. Osteoma of the orbit is the name usually applied, erroneously, to these growths, as they early invade that cavity, but the term

* Arch. f. klin. Chir., xxvii., 589.

should be restricted to those rare sessile osteomata which occasionally do arise in the orbit, more often near the inner canthus, and which are usually of specific origin.

Virchow termed these tumors endostomata and distinguished two forms: (1) those which arise in the diploë, and (2) the common type. They are, therefore, often called enostoses, but, although they are completely surrounded by bone by reason of their originating in the sinuses, the common form arises superficially and is not an enostosis in the true sense of the word.

The tumors, according to Arnold and the majority of observers, are of chondral origin, arising from persisting fragments of the chondrocranium, which in early fœtal life surrounds the outgrowths of mucous membrane from the nasal cavity that are later to form the accessory sinuses. The sphenoidal sinus and the antrum are formed thus at about the sixth month of intrauterine life, while the ethmoid and frontal sinuses are not formed until after birth. In the walls of these sinuses remains of the chondrocranium can be demonstrated for a considerable length of time, although no cartilage has ever been found in the tumors themselves, and they are consequently considered fibrous by many.

The growths are, therefore, analogous to chondral exostoses and, in common with them, are usually first noticed about puberty or during early adult life; eighty-seven per cent of the cases occurring before the age of thirty (Bornhaupt).

The predisposing causes are unknown, but trauma is often mentioned.

Pathology.—The tumors originate in the frontal sinus, usually at the inner angle, as small, warty excrescences, and grow slowly, shaping themselves to fit the cavity. In the course of a short time they become too large for this cavity and expand its walls, usually at the inner canthus, until by pressure they cause absorption of the bone and break through into the orbit, where they continue to grow, displacing the eye. At the point where the tumor enters the orbit it presents a distinct constriction or neck. The orbit, however, is not the only region which the tumor may invade; it may extend into the maxillary antrum or other neighboring cavity, or into the anterior fossa of the skull, displacing the frontal lobes of the brain (Fig. 183). An invasion of this latter region occurs in about seventeen per cent of the cases. Most of the tumors, when small, have a comparatively broad

FIG. 183.—Ivory Exostosis of the Frontal Sinus, involving the Orbit and Anterior Fossa of the Skull. Death from brain abscess. The anterior portion of the growth was removed at the operation. (Warren Museum, Harvard Medical School.)

base, but, as they increase in size, this part of the growth remains at a standstill, and consequently when recognized they are distinctly pedunculated. In their general aspect they are at first round, later becoming irregular in shape, lobulated, and surrounded by a thin shell of bone formed of the walls of the cavity in which they arose. The chief characteristic of these tumors is their extreme hardness. On section they are found to be covered by mucous membrane, under which is the periosteum. The tumor itself is composed of a thick outer portion, of extremely hard, ivory-like, somewhat lamellated bone, and an inner portion, small and easily overlooked, of red cancellated bone, often compared to pumice stone. Their construction is more marked at the base, which is the only place where the tumor can be attacked with any hope of removing it in its entirety.

When one of these growths originates in one of the other accessory sinuses, the orbit—owing to the slight resistance which its walls are able to offer—is usually, as happens in the case of an exostosis in the frontal sinus, the first cavity to be invaded by the growth. With the larger tumors inflammatory changes, such as panophthalmitis, empyema of the sinus, and brain abscess, are common. Occasionally, what has been termed a "dead osteoma" is found; that is, one which, owing to sepsis or rupture of the base, has become necrotic. Such an osteoma appears as a free solid mass of bone, devoid of periosteum and located in an irregularly shaped cavity.

Symptoms.—The tumor at first causes no symptoms. As it increases in size inflammatory changes are apt to occur; and when the frontal sinus is the seat of the growth there may be an empyema. Externally, the first symptom indicative of the presence of an exostosis in the frontal sinus is a bulging at the inner canthus or in the middle of the forehead. As this swelling increases (Fig. 184), the eye is forced downward and a little forward. When the sphenoidal sinus is the cavity from which the exostosis invades the orbit, the disturbance of vision is apt to be more marked and there is often panophthalmitis. If the surrounding skull has become involved, brain abscess may occur, or, more commonly, there is dizziness, headache, irritability, or epilepsy. When the growth is located in the nose it simulates for a long time a simple polyp, on account of the extremely thick covering of mucous membrane.

Diagnosis.—The diagnosis is comparatively easy, the cardinal symptoms being a slowly growing, hard tumor which appears at about puberty and displaces the eye. It is important to obtain a radiograph in order to determine the size and shape of the growth and also for the purpose of excluding sarcoma.

Prognosis.—The prognosis depends on the size and the seat of the tumor. Those of the nose, ethmoid cells, or antrum are much more easily removed than those of the frontal or sphenoidal sinus. The latter are also more dangerous on account of the frequency with which they involve the cranial cavity. If left untreated the tumors grow until they reach a large size, often forcing the

eye completely out of the orbit, but, as they are essentially of slow growth, this does not occur for many years. If they "die," they have been known to be thrown off spontaneously. Tillmann reports six cases in which dead osteomata were found accidentally at autopsy.

The operative mortality, as appears from the various collections of cases, is extremely high, but at present, in selected cases, with good technique, it should not be great. Out of 20 cases of osteoma of the frontal sinus there

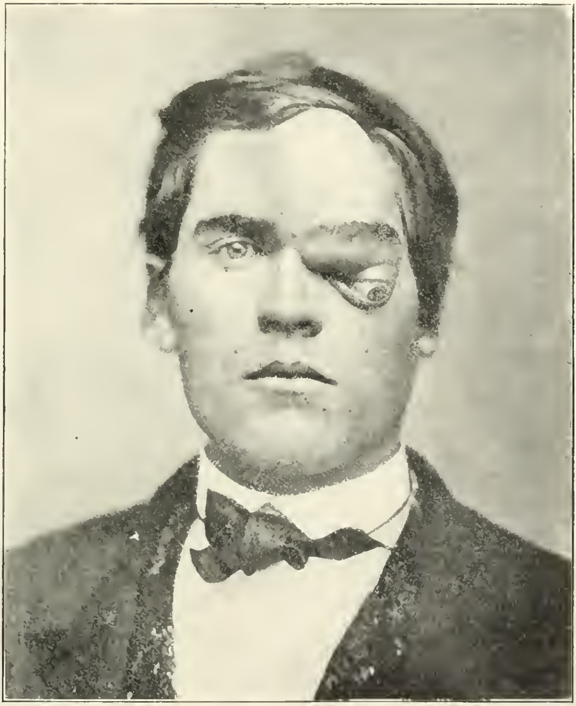


FIG. 184.—Ivory Exostosis of the Frontal Sinus. (Massachusetts General Hospital.)

were 9 deaths (Tauber*). Osteomata that are located in the sphenoidal sinus are extremely difficult to remove, while the operative removal of those which are located in the nose, antrum, or ethmoid cells is comparatively simple.

Treatment.—The treatment varies according to the size and the position of the tumor, and general rules only can be given. It is useless, in any case, to attempt removal of the growth piecemeal, as the bone is so hard that it will

*Centralbl. f. Chir., July, 1898.

turn the edge of any saw or chisel. The proper procedure is to remove the anterior wall of the frontal sinus and endeavor to find the pedicle, which can be easily divided; or, if this should also prove to be hard, the bone from which it springs and which is always thin and brittle, may be cut away with the tumor, care being taken not to open into the cranial cavity. The other bones of the orbit are then cut away until the tumor can be removed as a whole. The same general procedure should be employed when the tumor arises in one of the other sinuses. The operation being difficult and long, some authors have advocated the removal of the eye, as the tumor is benign, grows very slowly, and is apt to become "dead." This treatment, however, is not generally advised.

Multiple Cartilaginous Exostoses.—(Synonyms: Osteogenetic exostoses; exostoses de croissance; chondro-dystrophia; rachitis nodosa.)—This disease is seen in young subjects; it appears at about puberty and is characterized by multiple cartilaginous exostoses, associated with marked deformity of the skeleton.

The term should be strictly confined to this class of cases and not applied to the multiple small hyperostoses, of inflammatory origin, which arise from the periosteum and are at times seen in syphilis, in tuberculosis, and in chronic joint affections. The disease is not uncommon, the number of exostoses varying up to two hundred or more. Cases have been reported in which, in conjunction with the exostoses, there have existed chondromata, hypertrophies, hyperostoses, and partial gigantism; these varied conditions indicating that the disease is probably a general systemic disorder affecting the entire skeleton.

The disease is seen at or about puberty and occurs with equal frequency in both sexes. The influence of heredity is unquestioned and at times marked, a large number of cases having been traced through several generations. Lippert* has reported a series of seven cases in four generations, the disease having been transmitted through the female; while in other series it has been traced through the male. Lippert's cases are as follows:

		son	
	daughter	daughter	daughter
MOTHER	(9 normal	daughter	son
	children)	(6 normal	(2 normal children)
		children)	

Of the other predisposing causes but little is known. Volkmann, from his observations, came to the conclusion that all cases had a history of antecedent rickets, and suggested the name of rachitis nodosa. That, in infantile rickets, portions of the epiphyseal cartilage may be cut off and may later form exostoses or chondromata, has been definitely shown, but this disease is not always present, although in a few cases it may play a certain rôle. Out of twelve

* Deut. Arch. f. klin. Med., 1903, lxii., 913.

cases, Grosse* obtained a history of rickets in seven. Syphilis and tuberculosis have also been given prominent places in the etiology, but there is nothing to prove that they bear any relation to the disease. The exostoses, in these diseases, are fibrous in character and inflammatory, and, in syphilis, are usually seen on the skull, where cartilaginous exostoses are never found. Heymann has reported several cases associated with tuberculosis, but his observations have not been generally corroborated. Trauma bears no relation to the multiple exostoses.

FIG. 185.—Multiple Cartilaginous Exostoses in a Male Twenty-one Years Old. Note the shortening of the upper arms and the symmetry of the exostoses of the tibiæ. (Massachusetts General Hospital.)

All the bones in the body may be affected, with the exception of those of the head and face, but certain ones are more commonly involved than others. Thus, the upper part of the body is more often the seat of the exostoses, and the deformity is usually greater on the left than on the right side (Fig. 185). The long bones are chiefly affected, those of the forearm and lower leg and the upper end of the tibia usually showing the greatest change. The bones of the hands and feet, however, are rarely involved. The femur and humerus also show numerous growths, and they frequently occur on the pelvis, scapula, and ribs, while the vertebræ and sternum are rarely affected. The exostoses arise at or near the epiphyseal line and grow backward over the shaft as in the single form. They are best developed in the lower end of the femur or in the upper end of the tibia, where they may be long and branching. In other localities—as, for example, the lower end of the radius—they are seen as irregular masses, of varying size, surrounding the end of the bone and extending for a considerable distance up the shaft. Although by far the greater number of these cases show the exostoses at or near the epiphyses, in certain others they arise near the centre of the shaft, but are tipped with cartilage and are identical with the

* Rev. d'orthopédie, 1899, x., 466.

common form. The point of origin of these is disputed. They may arise at an early stage of fœtal development from the cartilaginous centre of ossification of the shaft (Fischer; Lippert) or from a bit of epiphyseal cartilage which became isolated very early in life (Bessel-Hagen). The deformity, which is a marked feature of the disease, is usually greatest in the forearms, and is caused, not only by the presence of the multiple growths, but also by a relative lack of development of the bones. Bessel-Hagen's theory was that there was enough epiphyseal cartilage to form a normal adult bone, but that if some of this was utilized in forming exostoses there would be a degree of shortening equal to the amount of the exostoses. Although there is doubtless some truth in this explanation, it certainly does not always hold, inasmuch as cases have been reported in which one of the bones, the seat of many exostoses, was longer than the corresponding one on the opposite side, which was only slightly involved, and also because the affected bone may be considerably longer than is normal relatively to the height of the individual. In the forearm this deformity may be very great, and is due to the lack of development of one bone while the other is of comparatively normal length. It is seen as ulnar or radial displacement of the hand, with bowing of the arm, and if the displacement is very marked there is often a dislocation of one of the bones at the wrist or elbow (Fig. 186). In the other bones deformity may occur, but is never as marked.

This disease is intimately related to multiple chondromata, and in fact both kinds of tumors often exist in the same patient. Chondromata and exostoses arise in the same manner, are seen in rachitic patients, and are to a certain extent hereditary. Typical cases of the two diseases are unlike in that different bones are affected; the small bones of the hands and feet being most often involved in multiple enchondromata, and these tumors manifesting a tendency to retrograde changes into malignant disease.

Microscopically, the exostoses are similar to those of the single cartilaginous variety, and the bone is formed in the usual manner.

Symptoms.—The disease causes few, if any, subjective symptoms. The onset is gradual, the patient first noticing, usually between the tenth and twelfth years, the presence of small irregular tumors around the joints or on the ribs. These tumors increase in size and number, and the skeleton at some point undergoes a gradual deformation, as in the forearm, where the growths cause a deviation of the hand toward the affected side, while the limb as a whole will often be shorter than usual. Pain may be caused by friction of the muscles on the growths or by pressure on nerves, but this symptom is unusual. Fracture of a growth of the long branching variety may occur and is associated with much pain. Then, again, a trauma may excite an exostosis to rapid growth. The tumors, unlike the enchondromata, continue to grow until the formation of the skeleton is complete; after which they remain stationary, undergoing no change during adult life. If one or more of the tumors should continue grow-

ing, this circumstance would warrant the belief that it is a chondroma and not an exostosis.

Diagnosis.—The diagnosis is usually very evident, the main feature being the presence of multiple hard tumors in the neighborhood of the epiphyses

Fig. 186.—Multiple Cartilaginous Exostoses. Shortening of the ulna with consequent bowing and dislocation of the radius. (Massachusetts General Hospital.)

in young adults or children, associated with a certain degree of deformity. The x-ray examination gives a typical picture and serves to exclude chondroma. The exostoses occurring in syphilis, infectious diseases, rarefying ostitis, osteo-

arthritis, etc., are fibrous, are not necessarily associated with the epiphysis, and occur later in life, and the etiology is usually evident.

Prognosis.—The prognosis is good as regards life, but there is always the possibility that a chondroma or a chondro-sarcoma may develop.

The progress of the disease cannot be arrested by any form of treatment; consequently the exostoses, if not removed, will continue to grow, and the deformity will increase until the full growth of the body is reached. The position of an exostosis may cause serious symptoms, as when it is situated in the pelvis, in women, in whom it may interfere with childbirth.

Treatment.—There is no treatment known that will cure or arrest the progress of the disease. If the exostoses are few and pedunculated they may be removed. They also should be removed when they interfere mechanically with the movements of a joint, or when they are in a position where they are constantly exposed to trauma. If a chondroma exists it should be removed early, that is, while it is still comparatively small. It will usually be well encapsulated, and consequently may be shelled out with comparative ease, leaving a useful limb.

CHONDROMA.

True chondromata, or enchondromata, are tumors composed of cartilage. The term should be restricted to those tumors of which cartilage forms one of the integral parts, and should not be applied to those which originate in the finished bone and which contain cartilage, bone, etc., as in these the tissue may represent only broken-down skeletal parts—in other words, may have nothing to do with the growth of the tumor itself. We can, therefore, only speak of a mixed tumor provided one of its characteristics be that of forming cartilage, bone, etc. (Borst*). The chondromata are, however, rarely pure, but are prone to degenerative changes, such as colloid, fatty, hyaline, and mucous degeneration, and also to retrograde changes into myxoma and sarcoma. In other cases, the chondroma may undergo a change into bone, and there are certain forms of this variety of tumor which tend to develop into chondral exostoses. Owing to their method of growth and the necessity of having intersecting bands of fibrous tissue between the lobules, in order that the blood-vessels which accompany these bands may bring to the parts their needed supply of nourishment, these cartilaginous tumors may present a distinctly fibrous construction (chondro-fibroma). On the other hand, if the fibrous tissue is markedly rich in cells, the growth may properly be termed a chondro-sarcoma.

Virchow divided the chondromata into two main groups: (1) the ecchondromata or cartilaginous tumors arising from pre-existing normal cartilage;

* "Die Lehre von den Geschüwlsten," 1902.

and (2) the enchondromata or cartilaginous tumors that develop where cartilage is not normally present. The terms enchondroma and ecchondroma are also at times applied to these tumors with the view of designating their position—that is, of indicating whether they originate in the marrow or on the outer side of the bone.

The *ecchondromata* are comparatively rare and of minor importance. They are seen as nodular or tuberous outgrowths from the cartilages of the ribs, vertebral discs, the symphysis pubis, or, in old people, from the articular cartilage. They are also seen arising from the tracheal rings or from the larynx; they are usually small, rarely exceeding an inch in diameter, and may be said to represent a hyperplasia of the normal cartilage. They are also seen in the joints, where they are usually of small size but are apt to cause marked functional disability. In this locality they develop as the result of an overgrowth of the articular cartilage, which overgrowth may later break off and form a free cartilaginous body within the cavity of the joint. Such bodies occur often in deforming osteo-arthritis and may be present singly or in large numbers. After the formation of these growths and their separation from their point of origin, they continue to grow as free bodies, deriving their nourishment from the synovial fluid. They are composed of a nucleus of hyaline cartilage, sometimes partly ossified, or of myxomatous tissue surrounded by fibro-cartilage, and they usually have a fibrous capsule; but by no means all the so-called "joint mice" are formed in this way. The manner in which free bodies are formed in otherwise sound joints is a disputed question, but it is generally conceded that they do occur, and that they are, in most instances, of traumatic or inflammatory origin.

The *enchondromata,* which constitute the largest and most important group of cartilaginous tumors, occur in any bone in the body, but more often in the long bones, those of the hands or feet being most commonly affected. They are seen in general where ossification occurs late, as in the neighborhood of the epiphyses or the synchondroses, and they may be either single or multiple, large or small.

Etiology.—There are many theories in regard to the etiology of chondromata, all of which undoubtedly have a bearing on the cause and in many cases explain the growths perfectly, but it is certain that the origin varies in different cases and it will not do to generalize too much, each tumor demanding special investigation. It is generally conceded that in most cases they are due to disturbances occurring during the formation of the skeleton and interfering with the relation of its component parts (Virchow). If this explanation be correct, these growths should be seen most commonly during the first two decades of life—the period of formation of the skeleton; and this, in fact, is what is observed. Virchow came to the conclusion that they arise from islands of cartilage isolated from the epiphyseal cartilage—islands which remained behind, as the bone grew,

and later formed tumors. This has been shown to occur in certain diseases, notably in rickets; and, although the conclusion which Virchow drew at that time was based upon a single case, many observers have since corroborated his inference. Rickets, therefore, has an important place in the etiology of chondroma (Volkmann), but occasionally other diseases cause similar irregularities in the growth of the transitory cartilage. These cut-off portions of cartilage do not in all cases go on to the formation of tumors, as islands of microscopic dimensions have often been demonstrated in the ribs and other long bones in adults who have suffered from rickets in childhood. They may be found in the marrow, or subperiosteally, at any point in the shaft of the bone, and trauma in later life may stimulate them to renewed growth. In this way are explained the chondromata which occur in persons of advanced age. Chondromata arising from this cause are very apt to be multiple.

Heredity plays a recognizable part in the etiology of chondroma, cases having been traced through several generations. These hereditary forms occur in one generation as single, in the next as multiple tumors, or *vice versa*, and it is not uncommon to have one member of a family affected with multiple enchondromata and another with multiple exostoses (Bessel-Hagen). The two conditions also may exist in the same patient, the chondroma being either benign or malignant in character. This disease is transmitted by either parent, and in the offspring affects either sex, but is somewhat more common in the male. Next to rickets or allied diseases heredity probably plays the most important rôle in the formation of multiple chondromata. von Bergmann, on the other hand, considers multiple chondroma a definite disease of the transitory cartilage.

The disease has been claimed by some observers to be a prenatal disturbance, the displacement of the cartilage occurring before birth, but not necessarily being of embryonic origin; and Ribbert considers an intra-uterine followed by an extra-uterine disturbance the probable cause in most cases—that is, he considers that in both the early and the late forms the *Anlage* of the tumor was present at birth and was not formed during the growth of the bone in childhood.

Embryonic disturbances, with a primary displacement of the cartilage germs, are of importance in certain cases, particularly in those in which chondroma is located in the soft parts, such as the lung, parotid, etc.

von Recklinghausen reported a case of multiple chondromata, associated with multiple cavernous angiomata, without a corresponding increase in the size of the main vessels of the limbs; the tumors in this case being situated mainly on the hands and feet. He attributed their growth to an insufficient blood supply and consequent inability of the transitory cartilage to form bone, vascularization of cartilage being necessary for this change. Indeed, von Recklinghausen maintains that this is the cause in most cases. However, evi-

dence in favor of this being the whole cause of chondromata is lacking, only one other similar case having been reported.

Retrograde changes of the marrow or periosteum into cartilage can and undoubtedly do occur, explaining in the aged the presence of chondromata; but such changes are uncommon in young subjects at the time when tumors of this type are usually seen.

Trauma.—Patients suffering from chondroma often give a history of trauma, and it is probably a more important factor in the causation of this variety of new-growth than is the case in any other tumor. Weber, in a large collection of cases made several years ago, elicited a distinct history of trauma in over

Fig. 187.—Cystic Chondro-sarcoma of the Femur. From a woman of eighty-two. (Warren Museum, Harvard Medical School.)

one-half the number. It cannot be said, however, to be the actual cause of the disease, but it probably stimulates the existing microscopic islands of misplaced cartilage to growth, while occasionally it may only call attention to a pre-existing tumor. In this connection it is interesting to note that chondroma is at times seen originating at the seat of a fracture.

As one would expect from their etiology, chondromata are more common in young subjects, usually being observed before the age of thirty, although they may occur at the extremes of life, cases having been reported in new-born infants and in people of advanced age (Fig. 187). In the former they are of embryonic or prenatal origin, and in the latter it is assumed that the collection of cartilage cells has been present since childhood or that it owes its origin to retrograde changes.

Bones Affected.—Any bone of the body may be affected, although the tumors show a marked predilection for certain bones. In multiple chondromata, as in multiple exostoses, certain groups of bones are affected, but, unlike what is true of the latter, the bones of the hands and feet are most commonly involved (Fig. 188). Thus, in 95 cases of multiple chondromata collected by Weber, the hands were involved 77 times, the feet 18. The single forms are also more commonly seen on the hands and feet, in which localities they are of the hard variety and not particularly malignant (Fig. 189). In the other long bones they tend to form in the diaphysis near the transitory cartilage, but they may be seen anywhere. Similarly, they are seen in the flat bones where ossification occurs late, as in the neighborhood of the synchondroses. Certain of the long bones are more apt to be involved than others. Thus, the humerus is more often affected than the bones of the forearm, and the femur and tibia

Fig. 188.—Hard Chondroma of the Finger, of Eight Years' Duration. From a girl of fifteen. (Warren Museum, Harvard Medical School.)

rather than the fibula. After the long bones, in the order of frequency, the jaw, ribs, pelvis, scapula, and skull, especially the base, are attacked, and most rarely the vertebræ, clavicle, sternum, and hyoid.

Pathology.—Simple chondromata are seen as irregular, lobulated, new-growths of varying size, some reaching enormous proportions, and are covered, in most cases, by a distinct capsule corresponding to the perichondrium, which, however, may be absent. As cartilage contains no vessels, the mode of growth of a chondroma is peculiar. von Rindfleisch believes that each lobule starts from a separate, definite focus of cells, but, whether this is so or not, there are developed cylindrical or irregularly shaped islands of cartilage separated by bands of fibrous tissue, and it is the presence of these which gives to the growths their lobular appearance. The nourishment of cartilage is little understood,

but it is probably effected by absorption from the blood-vessels or lymph channels which are in the interlobular fibrous tissue. If obtained in this manner it must necessarily be small in amount, and, therefore, it is not usual to find chondromata of large size, unless very fibrous, which do not show marked degenerative changes. The growth of a chondroma takes place internally or from the surrounding perichondrium, as in normal cartilage, and as the tumor grows it pushes aside without infiltrating, as a rule, the neighboring tissues, following somewhat the line of least resistance. When a vein or a lymph vessel is reached it is not uncommon for a prolongation of the growth to extend

FIG. 189.—Chondral Osteoma of Metacarpal Bone. (Original.)

into it, and fragments may become separated from the main mass and continue to grow independently, forming in this manner metastases. This event is of rare occurrence in small chondromata of the hands and feet. The amount of fibrous tissue present in a chondroma varies greatly, and in turn the degree of vascularity is proportionate to the amount of fibrous tissue present. When the blood-vessels are numerous, bone may develop as the result of over-vascularization.

The appearance of a chondroma varies somewhat with the place of origin. Thus, if it develop in the medullary cavity, it will tend to extend longitudinally in both directions, destroying the trabeculæ by pressure and distending and

thinning the cortex until the growth breaks through at one or several points. Occasionally, the cortex becomes much thinned without breaking, and there is thus formed a thin bony capsule surrounding the growth. It is in this manner, supplemented by the liquefaction of the cartilage, that most of the bone cysts are formed. When the tumor develops under the periosteum, the latter may form a thick, fibrous capsule, or, on account of the irritation, new bone may be formed, giving the growth a bony capsule. With the advance in growth of these tumors, the bone in the immediate vicinity may be destroyed from pressure, and under these conditions pathological fracture is of common occurrence. The destruction of bone substance is seen most markedly in the fingers and toes in the case of multiple chondromata, but this defect is in part due to the inability of the transitory cartilage to form bone. On section the tumors appear as translucent, pearly gray refractive areas of cartilage, having occasionally a somewhat lamellated appearance, the lamellæ being separated the one from the other by dense, grayish bands of fibrous tissue containing vessels.

Microscopically, chondromata are composed of either hyaline cartilage, fibro-cartilage, or elastic cartilage, the hyaline form being by far the most common. In many cases, however, although the bulk of the tumor is composed of hyaline cartilage, there is a thin zone of fibro-cartilage directly under the capsule. The cells are at times arranged in columns, as in normally formed cartilage, but they are more apt to be irregularly placed, the richness in cells varying greatly in different parts of the same tumor and the cells themselves being much larger in the growing portions. They are contained in well-marked capsules, at times two or more being included in one capsule, and they may be multinuclear. They are often small, but vary greatly in size and shape; some are round or oval, and others stellate or provided with anastomosing processes, the latter forms being seen in the softer varieties of chondroma which approximate the myxoma and in which the cells are usually unprovided with capsules. As a rule, all varieties of these cells are found in a single tumor. The cells lie in a hyaline homogeneous ground substance which, near the capsule, may show a fine fibrillary structure (fibro-cartilage). When they are surrounded by a capsule the latter is fibrous in character and sharply limits the growth, but when the capsule is lacking the cells may be seen growing directly into the surrounding tissue. The interlobular fibrous tissue varies in amount and contains a variable number of thin-walled vessels; the cells also vary in number and the same variation is observed in the amount of fibrous tissue present (fibro-chondroma; fibro-chondro-sarcoma).

Degenerative changes are the rule in these tumors after they reach a certain size, and of these the cystic is perhaps the commonest. It is due to the liquefaction and mucous degeneration caused by insufficient nourishment. The hyaline, colloid, fatty, and mucous varieties of degeneration are also often seen, and to the tumors which show these changes the names chondro-lipoma,

chondro-myxoma, etc., are applied. Myxo-chondromata are very common, the combination of cartilage and myxomatous cells with branching protoplasm being seen in most of the larger growths (Fig. 190). Retrograde changes are also common, and the myxo-chondroma may be considered the product of one of these changes. Virchow distinguishes between chondroma mucosum on the one hand and chondroma myxomatosum or myxoma cartilaginosum on the other, the former tumor being a simple degeneration of the ground substance which is composed of mucin and chondrin, whereas the latter should be classed among the true mixed tumors. Calcification, which occurs

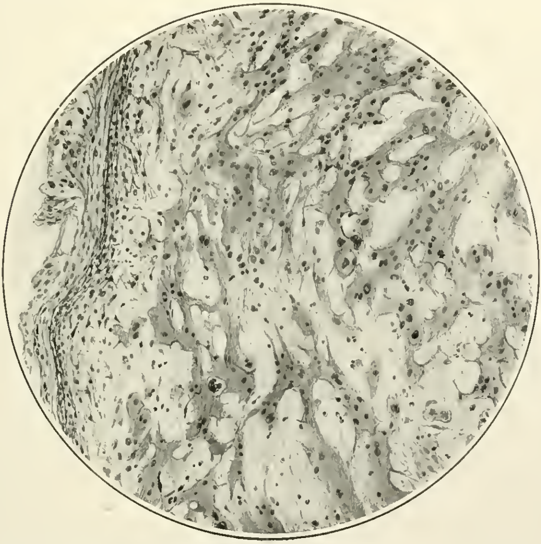


Fig. 190.—A Section from a Chondroma of the Sacrum. The tumor was composed mainly of hyaline cartilage, but this particular section shows considerable myxomatous degeneration. Near the capsule there is some fibro-cartilage. (Original.)

frequently, takes place either in the cells or in the ground substance, as does the progressive change of some portions of the cartilage into true bone; but this ossification is apt to be very irregular (osteo-chondroma). Strictly speaking, this term should be applied only when it is a characteristic of the tumor to form both bone and cartilage. A chondral exostosis, a chondroma, and a chondrosarcoma may exist in the same individual, Loeven* having reported three such cases. In general, therefore, it may be said that in any of these tumors sections should be made from several portions, as any or all of the above-mentioned varieties may exist in the same growth.

* Loeven: Deutsche Zeits. für Chir., 1904, p. 14.

One form of chondroma upon which special stress is laid, especially by the German writers, is the osteoid of Virchow. This tumor, because of its malignancy, is often classed with the sarcomata, but in this country, at least, it seems to be a rare form of new-growth. It arises subperiosteally, either from the periosteum or from the shaft, and consists of columns of cartilage cells which usually have no capsules and which are separated by radiating trabeculæ and marrow spaces rich in vessels. The trabeculæ, however, are not calcified, although they may become so; in which case the growth resembles an osteosarcoma.

Symptoms.—The symptoms of chondroma are those common to any tumor of the bone, and naturally vary with the position of the growth and the particular bone involved. Pain is neither a constant nor an important symptom, being observed only when a large nerve trunk is involved, or occasionally when the growth is central. Œdema from pressure on the vessels is sometimes noticed. Pathological fracture is of common occurrence, particularly in the central forms, and is seen after slight violence, being at times the first symptom that calls attention to the condition. A tumor, which varies in shape and size according to its location, is usually present. Commonly it is rounded and lobular, but in the long bones it may produce a fusiform swelling not unlike that caused by a sarcoma, particularly if it be centrally situated. As a rule, it is hard, but it may be elastic and in some cases even fluctuating. When it is soft, although at the same time surrounded by a bony capsule, the characteristic crackling, that is often mentioned in connection with similarly situated tumors, but is rarely found in them, may be elicited. In the multiple form the resulting deformity is of course great, and in the long bones bowing is often observed. The rate of growth varies considerably, being much more rapid in the softer types.

Diagnosis.—In the multiple form the diagnosis is comparatively easy, and is based on the number of the tumors and their location. In single chondromata, however, it is more difficult and clinically often impossible to differentiate the tumor from a sarcoma. A tumor that develops in a young subject, that manifests progressive growth, that is situated near the epiphysis, and that does not cease to grow with the complete formation of the bony skeleton, is either a chondroma or a sarcoma. Cartilage casts no shadow with the *x*-ray, but appears as a hole or as a defect in the side of the bone, and consequently osteoma is easily excluded, as are also some forms of sarcoma; but it is impossible in many cases to differentiate between a central sarcoma and a chondroma.

Prognosis.—The prognosis varies with the type of the growth and its position. Chondromata are distinctly more malignant than osteomata, and are by many placed with the malignant growths. In general, it may be said that the hard forms are much less malignant than the soft, the latter being nearer the embryonic type of tissue, which is unstable and prone to retrograde changes.

Nevertheless, the hard forms occasionally form metastases when they reach a considerable size, either by growing into lymph channels or the blood-vessels and being carried to the lungs or lymph nodes, or, more rarely, by making their way into the neighboring tissues by direct progression. In the long bones multiple small foci of cartilage may be seen in the shaft when one end is the seat of the tumor, but in these cases it is probable that they represent multiple tumors and not metastases. The soft types may either infiltrate the neighboring tissues or they may form metastases in the usual way. Those tumors which have a distinct sarcomatous element call for the prognosis that belongs to sarcoma. As the chondromata are of progressive growth, and in the young do not cease with the formation of the skeleton, the prognosis, without operative interference, is bad, for, even if they should not undergo retrograde changes, they may reach enormous size. In the multiple form, although the tumors rarely become malignant, the growths exist in such numbers that operative treatment with the idea of eradicating all the tumors is hopeless, and great deformity and disability often result in these cases. The prognosis also varies with the position of the tumor and its accessibility to operative interference; those tumors which involve the long bones warranting a more favorable prognosis than those which are situated in the skull or the pelvis, or which spring from the vertebræ.

Treatment.—Operative removal constitutes the only available treatment, and the degree of success which may be expected from it depends on the location and the form of the growth. In the case of the hard, encapsulated tumors that involve the exterior of the long bones, it is only necessary to remove the growth, which, in the majority of instances, can easily be shelled out. If, however, it has already attained a large size and has caused some destruction of the bone, it will be found necessary to amputate above the growth and its metastases, provided the presence of the latter can be demonstrated. When a simple removal is practised it is well, in the cellular forms, when possible, to remove at the same time some of the adjacent soft parts, in order to prevent a recurrence. In the multiple form amputation or enucleation is also to be thought of, but it is generally useless to operate with the idea of effecting a permanent cure. All that can be done under these circumstances is to eradicate the larger growths and relieve the symptoms of pressure and deformity as they arise. In the softer and more malignant forms the same question comes up as in sarcoma, *i.e.*, whether it is better to amputate or to excise; and the choice of operations depends somewhat on the size of the tumor and on the parts which are involved. It is, of course, useless to amputate if there are signs of metastases in the lungs, and many surgeons, even in the most malignant forms, advocate excision, as there is a fair chance that the disease may not return locally, and if it does the tumor may be removed at a second operation. (See the section relating to treatment of bone sarcoma, farther on in this article.)

Chondromata of Special Regions.

Scapula.—Chondromata of the scapula may reach an enormous size. Walder collected in 1891 all the cases operated upon to date, 25 in number, and later Deganello* reviewed his cases and added 14 that had been reported subsequently. In Walder's statistics 17 out of the 21 in which he was able to determine the age, were less than thirty years of age. In 23 of the 39 cases the disease was simple chondroma; and of the 30 cases in which the sex could be determined, 18 were men and 12 women. The lower portion of the scapula is most frequently affected, then the spine, the acromion, and the upper inner angle, in the order named. The operative mortality in excision of the scapula, or in amputation of the shoulder girdle, for chondroma, appears from the statistics to be high, but in all probability it is much lower in selected cases, as many of these operations were done before the days of aseptic surgery. The difference in the tendency to recurrence between the simple chondroma (*i.e.*, the hard variety with degenerative changes) and the soft form with retrograde changes appears clearly in the statistics. Thus, in 11 operations on the hard chondroma there were 2 recurrences, while in 10 of the soft variety 3 returned locally and 2 gave metastases. In the 21 operations on tumors of the scapula —comprising everything from simple removal of the growth to excision of the scapula or amputation of the upper extremity—there was a mortality of thirty-five per cent.

Pelvis.—Pelvic chondromata, which are more common in the female than in the male, are of importance on account of the obstruction which they cause to childbirth—an obstruction which may even render the birth of the child by way of the vagina impossible. Chondromata in this locality may be divided into two main classes—those originating within and those without the pelvic cavity, the latter class being of little importance. These external chondromata are usually situated near the sacro-iliac synchondrosis, but may also be seen on the descending ramus of the pubis, or on the ascending ramus of the ischium, and also in connection with the coccyx or with the cartilage of the symphysis pubis. Those which are located within the pelvic cavity nearly always originate in the neighborhood of the sacro-iliac synchondrosis and are of rather rapid growth. The symptoms vary according to the structures which are pressed upon, the obturator and sciatic nerves being commonly involved. Constipation is common and bladder symptoms are to be expected when the tumor reaches some size. Œdema of the legs is often present. The diagnosis of a tumor of the pelvis is made with comparative ease by rectal or vaginal examination, but the character of the growth is very difficult to determine, as all forms of osteoma, sarcoma, fibroma, and chondroma feel much the same. Radiographic examination is of value in ruling out osteoma; and the smooth,

* Deganello: Virch. Arch., 1902, 168–265.

lobulated feel of chondroma is, in many cases, quite characteristic. The proper treatment is removal by operation, and Domke* was able, in 1895, to collect 15 cases operated upon with a mortality of twenty-six per cent; and more recently Zeller† has written upon the same subject. Three of these cases were both internal and external, 7 simply external, and 5 internal. The mode of operating varies considerably with the location of the tumor. Some surgeons approach it through the abdomen, while others enter the pelvis by an incision in the perineum along the descending ramus of the pubis. Codman, in one case, entered the pelvis through an incision carried from the superior spine of the ilium, parallel to Poupart's ligament, and then down along the course of the femoral vessels. Many of these chondromata of the pelvis are pedunculated, and when this is the case they are of course much easier to remove: but this is not true of all these growths, one case reported by Gussenbauer having a base of fifty-five centimetres in circumference.

Skull.—Chondromata of the skull are rare tumors, but they are occasionally seen both externally and internally, although the common point of origin is at the spheno-occipital synchondrosis. They are also seen in the ethmoid and in the jaws, and may of course be connected with any of the bones. In the vertebræ they are also rare, and in this situation they usually spring from the intervertebral discs and form flat tumors on the anterior surface of the column. They may also cause paralysis from pressure if they invade the canal.

A few rare cases of chondroma of the *hyoid bone* have been reported.

CHORDOMA.

(*Chordoma*, Ribbert; *Ecchondrosis prolifera seu physaliphora*, Virchow.)

Chordomata are tumors that develop at the spheno-occipital synchondrosis. Theoretically they are of importance, but clinically they are not, as they never attain great size and cause no symptoms, being found, as a rule, accidentally at autopsy. They were first described by Virchow, who believed them to be of cartilaginous origin, but Ribbert‡ has later shown that they probably consist of proliferated remains of the notochord. Small areas of tissue similar to that found in this tumor may be seen in the bodies of any of the vertebræ, but these areas do not attain any considerable dimensions except in the clivus Blumenbachii. Ribbert was able to demonstrate the presence of a chordoma in two per cent of the cases of autopsy.

The tumor originates in the marrow of the bone and invades the cranial cavity, where it has a somewhat pedunculated appearance and is in close relation to the pons. It is soft, gelatinous, and consists microscopically of masses

* Domke: Arch. für klin. Chir., 1895, L, 177.

† Zeller: Deutsche Zeits. für Chir., 1903, 4, 538. ‡ "Die Geschwulstlehre," 1904.

of rounded, bladder-like cells, with clear protoplasm and comparatively small nuclei lying in a hyaline matrix. The tissue somewhat resembles that of cartilage.

The tumor causes no symptoms, on account of its small size and extreme softness, and the diagnosis is impossible during life.

BONE CYSTS.

Bone cysts are of rare occurrence, and until recent years comparatively little was known about them, the etiology in many cases being even now obscure. They are seen more commonly in the epiphyseal ends of the long bones and usually are the result of the degeneration of pre-existing tumors. Primary cysts with epithelial lining—except those of the jaw arising from a malformed or misplaced tooth follicle (follicular odontoma), and the dermoid cysts of the skull—do not exist. From a pathological standpoint, therefore, cysts of the bone should be considered with the diseases or tumors in which they occur, but clinically it is more convenient to consider them as a separate and independent class.

They may be divided into various groups —

(1) *Primary cysts:* *a*, odontoma; *b*, dermoids; *c*, cysts of the air cavities (ethmoid, sphenoid, maxillary, frontal).

(2) *Secondary cysts:* *a*, due to animal parasites—echinococcus, cysticercus; *b*, in diseases of the skeleton—ostitis deformans, osteomalacia; *c*, in inflammatory conditions—arthritis deformans, osteomyelitis, etc.; *d*, due to degeneration of tumors—enchondroma (common form), sarcoma (blood cysts), any tumor.

(3) *Cysts of unknown origin.*

Bone cysts were first described by Dupuytren, in 1834. He employed the term, however, for all tumors originating in the bone, and distinguished a "solid" and a "fluid" form. Stanley, in 1849, and Holmes, in 1870, denied their existence, maintaining that all cysts of the bone were either degenerated sarcomata or hydatid cysts; and it was not until Virchow—who accidentally discovered such a cyst in the humerus of a young girl at an autopsy and was able to study it carefully—described them, that their existence and probable cause were determined. This was in 1876. His conclusions, based upon his observation in this case, were to the effect that cysts of the long bones are never primary, but are due to the degeneration of a previously existing tumor, usually a chondroma arising from a misplaced bit of epiphyseal cartilage. These conclusions, which account for nearly all the cases, are accepted at the present day. Since Virchow's original article was published, many observers have verified his statements. Koenig, in reporting a case and reviewing the literature, emphasizes the fact that the softening process takes place as fast as the enchondroma is formed, so that the etiological factor may not be recognized unless a care-

ful examination is made, and then often only by the aid of the microscope. If, in its growth, this misplaced bit of epiphyseal cartilage does not soften, it may produce a true chondroma; or, if it is displaced outward so that it occupies a position just under the periosteum instead of in the medulla, it may produce one of the cartilaginous exostoses commonly seen near the epiphyseal line, in young adults. Koch* collected 22 cases of bone cyst from the literature, and reported 1 of his own. In 17 of these cartilage was demonstrated in the cyst wall, and in 2 others the probability of their originating in this manner was great.

Although this is the cause of most of the bone cysts, the origin of certain others cannot be explained in this manner, as careful search has failed to demonstrate the presence of cartilage; negative evidence, however, is open to question. Cysts of this character have been described by Bloodgood,† Helbing, and Schlange. The latter observer at first considered his case due to rarefying ostitis, but in a later article admitted that the presence of cartilage was probably overlooked.

Many men have pointed out a relation between inflammatory processes and cyst formation, Ziegler mentioning cysts as occasionally occurring in arthritis deformans. He advances the theory that in these cases the cysts may be due to the bone undergoing a retrograde change into cartilage, and the latter in turn forming cysts. Multiple small cysts are also occasionally seen after an osteomyelitis.

Cysts are seen at times in ostitis deformans and somewhat more commonly in osteomalacia. In these diseases the cysts are multiple and are seen in any of the bones, not necessarily being situated near the epiphyses. They have been considered to be due to a liquefaction caused by the disturbance of nutrition.

Any tumor of the bone may undergo degenerative changes with the formation of cystic cavities, but these are of secondary importance and their etiology is very evident. Of this type the blood cyst of a central giant-cell sarcoma is the most marked form.

In the following remarks the single cysts of probable cartilaginous origin will alone be considered.

Cysts of bone are seen most commonly in children and young adults, and may be expected to occur in any of the long pipe bones; more cases having been reported, however, in the femur, humerus, and tibia. They develop in the diaphysis near the epiphyseal line and extend into the shaft, rarely if ever involving the epiphysis or the joint. For this reason no material shortening of the bone is observed. As to the predisposing cause, aside from the fact that they develop from cartilage, but little is known. In rickets it has been shown that portions of the epiphyseal cartilage often become isolated; conse-

* Koch: Arch. f. klin. Chir., 1902, lxviii., 678.

† J. C. Bloodgood: Journal of the American Medical Association, October, 1904.

quently this disease may play an important rôle in certain cases, although in others it certainly is not an etiological factor. Trauma also is of considerable importance; cartilaginous tumors, both of the bones and of the soft parts, being the commonest growths referable directly to this cause.

Pathology.—In the common form the end of the bone is distended in a varying degree, depending on the size of the cyst, and the cortex is thinned, but is rarely if ever broken through. The periosteum is usually normal and does not show any thickening or involvement in the growth, as is often the case when a medullary sarcoma is present. When opened, the cyst is usually found to be unilocular, to contain bloody fluid, and to extend for some distance down the medullary cavity. The lining of the cyst is in most cases characteristic; it consists of a dense fibrous membrane in which glistening pearly areas of cartilage may be seen. At times these cartilaginous areas are demonstrable in the medullary cavity at some distance from the borders of the cyst. In the rarer forms no lining membrane or cartilage is to be found.

Microscopic examination of the wall shows the lining membrane to be composed of dense fibrous and granulation tissue, in which there may be considerable blood pigment, but nowhere is there any evidence of epithelial structures. Beneath this lining membrane are seen trabeculæ which have a more or less flattened-out appearance, and between them lie small irregular islands of cartilage. The cartilage cells are of varying size and shape, many being polygonal with a large nucleus and comparatively small amount of protoplasm. Many of these cells are seen undergoing necrosis or mucoid degeneration. There is usually some attempt at new bone formation, and in the outer portion of the cyst wall osteoblasts are often seen.

In the rarer cases the cyst may be multilocular and of irregular shape, presenting no lining membrane and having no demonstrable cartilage in its walls.

In either of the two forms the appearances presented may be greatly altered by the existence of a pathological fracture and the resulting attempt at repair.

Symptoms.—The clinical picture of a bone cyst is at present fairly well recognized. The disease, as a rule, causes but little inconvenience in the early stages, the first symptom often being a fracture occurring either spontaneously or after a slight trauma such as an insignificant blow or fall. Pain may be present, but it is a minor symptom, and does not become specially noticeable until the cyst has attained considerable size. Even then it is rarely severe, nor is tenderness usually complained of until the later stages, often being absent entirely. In certain cases, however, the patient seeks advice for slight pain referable to the joint and for a certain degree of lameness; but an examination either reveals absolutely no recognizable changes or at most shows that there is a slight increase in circumference of the affected bone. If the disease is more advanced, an examination may reveal the presence of a smooth, somewhat fusiform swelling in the region of the epiphysis. This swelling, which may or

may not be tender, sometimes conveys to the touch the characteristic crackling sensation that is obtainable in any tumor having a thin, bony wall. When the first symptom is a fracture, the cyst may be overlooked, but the union of the fragments is apt to take place slowly and the resulting callus is considerably larger than would ordinarily be expected, remaining as a permanent tumor. There have been reported cases in which an osteo-chondroma has developed from the callus and the cartilage of the cyst wall.

The *x*-ray appearance of the cyst is, in many cases, as pointed out by Beck, quite characteristic (Fig. 191). It appears at the epiphyseal end of the dia-

Fig. 191.—Bone Cyst at the Upper End of the Femur, with Spontaneous Fracture. (Massachusetts General Hospital.)

physis as a tumor which distends the bone, and, although the cortex is much thinned, its outlines are smooth and regular, no change being observed in the periosteum. The cyst itself is seen in the negative as a smooth, dark shadow, becoming lighter near the edges. Myeloid sarcoma gives a somewhat similar appearance, but occurs later in life, and in addition bony trabeculæ are often seen traversing the cavity. In this form of sarcoma, usually,—and always in other forms of central sarcoma,—the cortex is rough and irregular, showing some involvement of the periosteum, and in parts it is often translucent, being replaced by the growth.

In other cases, as, for example, that reported by Bloodgood, the appearances presented are quite different from the description here given.

Diagnosis.—Although the presence of a cyst may be suspected, a definite diagnosis often cannot be made without an exploratory incision; it being impossible to rule out medullary sarcoma or some other form of central tumor. The possibility of a bone cyst should be considered in all cases in which a tumor develops in the epiphyseal end of a long bone in a child. Pain and tenderness preceding the appearance of a tumor or a pathological fracture is much more common in sarcoma, but the medullary giant-cell form, which is more apt to be confounded with a cyst than is any other form of sarcoma, is of comparatively rare occurrence in children, although it is probably seen as often as are cysts. The *x*-ray appearance, when characteristic, is the only thing on which, when the cyst is small, a definite diagnosis can be based. As a rule, however, sarcomata in children are very malignant, and if the tumor has been present for some months, without causing marked constitutional symptoms, the possibility of its being a cyst should be seriously considered.

Treatment.—As these growths are non-malignant, amputation is never justifiable. The operation usually employed is to make a longitudinal incision down to the bone. An opening is then made through the thin cortex and a portion of its anterior wall removed to give free access to the cavity, this being done subperiosteally if possible. The cyst cavity having thus been exposed to view, its contents, which consist of blood-clot or bloody fluid, should be evacuated and the interior of the cyst thoroughly curetted; or, if preferred, the walls of the cyst may be removed with a hand gouge, care being taken to remove all vestige of the cartilage. The cavity will be found, in most cases, to extend for some distance down the shaft, and a careful study of the skiagraph should be made to determine whether any isolated island of cartilage exists below the lower extremity of the cyst. If the cyst is multilocular, all the septa should be destroyed and removed. The cavity should then be packed with gauze, a splint applied, and the wound allowed to heal by granulation. In certain cases where the walls of the bone are thin, instead of packing the cavity one may advantageously fracture and fold in the walls, thus obliterating the cavity. Then the wound should be closed, and a temporary drain inserted at the lower end of the incision to remove the exudate. In certain cases this procedure has, according to Beck, given good results, but it should not be employed if there is much hemorrhage after removing the tourniquet, and, besides, the danger of infection is always greater than it is if the wound is packed. Other surgeons make no attempt to crush in the walls of the cyst, but allow it to fill with blood, and then close the skin wound without drainage. Mikulicz has reported a case in which he injected iodoform glycerin into the cyst. Two years later the skiagraph revealed the fact that the former cavity was completely filled with normal bone.

In certain cases of advanced disease a subperiosteal resection has been done with good result, but this method of treatment is rarely necessary.

The after-treatment consists of keeping the limb on a splint until the bone has united and the cavity has partially filled up, which occurs in from four to eight weeks. A sinus may persist for some time longer.

Prognosis.—The prognosis of operative interference in these cases is good. As a rule, chondromata do not tend to recur, and, as the joint and the epiphyseal cartilage are not involved, there is no interference with the growth of the bone or with motion

FIBROMA.

Fibromata of the bone are rare tumors and usually arise from the periosteum, but are occasionally seen in the medulla. They are observed more commonly on the flat bones than on the long, the head and face being the usual seats, but they may be seen in connection with any bone in the body. Many of the fibromata should be classed as inflammatory growths or as of congenital origin, while certain tumors, which at times are included in this group, are in reality dense spindle-cell sarcomata, it being impossible to draw a sharp line of division between these two kinds of tumors. Other tumors, that are often included in this group, are the fibrous odontomata of the jaw and the fibromata of parosteal origin.

The cause of fibromata, with the exception of those of an inflammatory nature, is unknown. Macroscopically, they are usually firm, grayish tumors, more or less vascular; but their consistence varies greatly. As a rule, they have a distinct capsule. Microscopically, they are composed of bundles of spindle or somewhat polygonal cells more or less closely packed together and intersected by numerous vessels. They often contain areas of calcification and at times true bone.

Fibroma of Jaw.—See the sections on Epulis (p. 457) and Odontoma (p. 471.)

Naso-pharyngeal Fibroma.—These and the similar fibromata of the accessory sinuses constitute a distinct class of new-growths, but their tendency to disappear after puberty has caused some observers to question the advisability of grouping them with the true tumors. They originate usually from the upper posterior part of the naso-pharynx, *i.e.*, from the base of the skull or anterior portions of the upper cervical vertebræ. They spring from the periosteum and are usually somewhat pedunculated, but they are very firmly attached to the bone. They are dense and very vascular and are often termed fibro-sarcomata.

Naso-pharyngeal fibromata are seen in adults under twenty and are rare after twenty-five. Males are more commonly affected than females, in the proportion of four to one. The tumors increase gradually in size, invading the

nares and often breaking through into the antrum. They may attain large dimensions. Ulceration with resulting hemorrhage is common, hemorrhage being one of the chief features of the disease.

The *diagnosis* is usually evident.

The *treatment* is removal by operation, and several procedures have been suggested. The main difficulty encountered is in controlling the hemorrhage, which is usually severe. The best operation is the removal of the growth with the thermocautery snare. Other operations practised are: the removal of the growth with the cold snare, curetting, electrolysis, excision of the upper jaw, etc.

Prognosis.—The results of operation were formerly poor and the operative mortality high. Without an operation the prognosis is worse the younger the age of the patient at the time when the tumor is first discovered, for it then has more time to grow. On the other hand, when the tumor appears at about the age of twenty it rarely attains a large size and may disappear spontaneously. Delavan has collected forty-seven cases in which removal was accomplished with the thermocautery snare with no operative mortality, and with but one recurrence and one failure.

Fibromata of Other Bones.—Fibromata are seen on the scapula, the vertebræ, and the pelvis more commonly than on the long bones, usually appearing at or before puberty. On the inner aspect of the pelvis, one of the most common seats of these tumors, they may interfere with childbirth. In a certain number of cases they spring from the anterior spine of the ilium, to which they are attached by a very small pedicle.

LIPOMA.

Lipomata constitute a comparatively rare and unimportant class of bone tumors. They may be said to resemble in general the lipomata that originate in the soft parts, and have been observed in almost all the bones of the body. Bland-Sutton, in 1885, was able to collect only seven cases, but since then many have been reported; Hurault, in 1900, tabulating thirty-one. They are in nearly all cases periosteal, but in a few reported instances the growths occupied the medullary cavity.

The cause of these growths is little understood. Virchow suggests that in the long bones they represent an inflammatory reaction around a slightly marked exostosis, and inflammatory conditions probably explain a great many of them. Some are observed in the immediate vicinity of diseased bone, the patient giving a definite history of osteomyelitis in childhood; while in other cases a history of inflammation resulting from trauma or periostitis is to be obtained. A true congenital origin has been suggested for certain

of these tumors in children, and some relation between them and multiple cartilaginous exostoses may exist, inasmuch as in the long bones they almost always develop near the epiphyses and are at times associated with other congenital deformities. In other cases the tumors are to be considered a trophic disturbance and are associated with changes of a similar nature in the soft parts. Probably the greater number represent fatty degeneration in previously existing tumors, and in this category should be placed the lipomata which are observed on the skull at the glabella and fontanelles, or over the cranial sutures, or along the back and at the coccyx. In these localities the tumors undoubtedly represent a spontaneous cure of a meningocele or spina bifida. Certain lipomata originating from the spine have been traced to the spinous process of a vertebra, and yet no malformation of the bone has been seen. In the jaw, where they may have a central origin, they in all probability represent fatty degeneration of some form of odontoma (fibrous or mixed). On account of the vascularity observed in some of these fatty tumors it has been suggested that they may be degenerated periosteal angiomata, and this may account for their rareness. Granular degeneration of muscle has been suggested as a cause (Pearce-Gould), and some have thought that the tumors may develop originally in the intermuscular septa and become attached to the bone in the course of their growth. In general, it may be said that in some cases they are of inflammatory origin, while in others they represent a trophic disturbance, and in still others a degeneration of previously existing tumors. It must also be accepted as a fact that some are congenital tumors arising through an unknown cause.

The growths occur in people of all ages, but are much more common in children, in whom they run a course somewhat different from that which they pursue in the adult. For this reason they are divided into two groups: (1) congenital lipomata, occurring in children, having a rapid growth, accompanied with marked general disturbance, and showing a tendency to recur after removal; and (2) those in the adult, of slow growth and resembling the lipomata of the soft parts. The congenital lipomata of unknown origin constitute a fairly definite group of tumors.

The order of frequency of the bones affected is commonly stated to be the following: the vault of the cranium, the vertebræ, the coccyx, the long bones, and the flat bones. The tumors connected with the spine and skull, however, as has been before stated, usually represent a cured meningocele, while those which may be classed as true congenital lipomata are probably more common on the long bones, where they are seen in close relation to the epiphyses, many cases having been lately reported in connection with the lesser trochanter. In a collection of twenty-seven cases found in the recent literature the bones were affected in the following order:—

Femur	9	Scapula	1
Clavicle	4	Palate	1
Skull	2	Radius	1
Vertebræ	2	Hand	1
Sacrum and Coccyx	3	Tibia	2
Pelvis	2		

The growths, as would be expected from the etiology, are more common in children, but they may occur in adults of even advanced age.

Pathology.—Lipomata of bone vary considerably in their consistence, some being soft and composed mainly of fat, while others—and these constitute the majority—are distinctly fibrous and very firm. They are usually lobulated and, in their growth, they extend between the muscles, following, as a rule, the line of least resistance. The capsule is at times well marked, but, unlike what is observed in lipomata of the soft parts, it is often wanting, the growth in that case infiltrating the muscle directly. The attachment of the tumors to the bone varies, some being connected to the periosteum by a narrow pedicle, while others are attached at several points, one of these representing the original attachment, while the others have probably formed as the result of inflammation. In still other instances the growth is firmly attached to the periosteum by a broad base, and may with difficulty be separated from it. At the point where the lipoma springs from the bone there may be an exostosis, or, as a result of pressure or through an extension of the growth, the bone itself may be partly destroyed. Deformity of the latter may also result from the pressure exerted by the tumor.

Microscopically, the lipomata of bone consist of fat and fibrous tissue in varying proportions. One characteristic of many of the growths is the presence of striped muscle—a phenomenon which may be due to the accidental incorporation of muscular tissue in the tumor; but in some instances the muscle evidently is an integral part of the growth.

Symptoms.—In many lipomata, particularly those developing from a cured meningocele and those arising in later life, there are no symptoms other than the presence of the tumor. These growths are extremely soft, semi-fluctuant, and either freely movable or more or less firly attached to the bone. Other symptoms, if any are present, are purely mechanical. Occasionally the veins over the tumor are distended.

In what has been termed the congenital form, which is seen in children and young adults, the tumor exhibits a rapid but painless growth, and is accompanied by progressive cachexia and debility, thus having all the characteristics of a malignant growth.

Diagnosis.—The diagnosis is often difficult, the extreme softness and the sense of fluctuation observed in these growths usually causing them to be considered cystic; such growths being generally looked for in the situations where lipomata are commonly found, viz., at the cranial sutures, along the spine, and

in the region of the trochanter. In children, lipomata are often confused with malignant tumors on account of the general disturbance. The radiographic examination of the growth is usually negative, but serves to rule out a tumor involving the bone itself, although no inference can be drawn, from the result of the examination, regarding the differential diagnosis between lipoma and one of the soft varieties of sarcoma that has developed in the soft parts near the periosteum. A cystic tumor may be ruled out by tapping, but this procedure is not justifiable in all cases. The removal of a piece of tissue by means of a punch is likewise not to be advised, as in case of malignancy there is always some danger of distributing the growth. It is therefore impossible in many cases to make a definite diagnosis, but the possibility that the growth in question may be a lipoma should be remembered.

Treatment.—The treatment consists of excision, the form of operation chosen depending entirely on the site of the growth. Unlike what is observed in the usual forms of lipoma, such excision may prove difficult on account of the tendency of the tumor to infiltrate. If it be found that such an infiltration has already taken place, it will be necessary to remove all the soft parts involved, especially in children, on account of the liability of the growth to return.

Prognosis.—In the adult the prognosis as regards operative removal is the same as in other forms of lipoma—that is, it is good, the growth being in all respects benign. In children, lipomata show a marked tendency to recur unless they are thoroughly removed. On account of the liability of the growth to infiltrate the muscles, it is necessary to remove some of the adjacent structures, and consequently a certain amount of disability may result from the operation.

ANEURISM AND ANGIOMA.

Aneurism of the bone, a term first applied by Pott and much used by the older writers, was supposed to be of fairly common occurrence, but, since Gentilhomme's article in 1863, most authorities have taken the stand that there are no such tumors, and they interpret all the so-called bone aneurisms as unrecognized broken-down sarcomata. Theoretically, it is possible to have an aneurism of the bone, as aneurisms may occur wherever there are blood-vessels. The vessels of the spongy bone, according to the observers who believe in the existence of these tumors, are ruptured as the result of trauma, and an arterial or venous varix then forms; but, if this were generally true, aneurisms of bone would be common, in view of the number of fractures that occur.

Five cases have been collected by Richet, and Oehler has reported thirteen, but, in the few cases in which a microscopic examination was made, the conclusions reached are not justified by the pathological findings, and are not in-

compatible with sarcoma (Gaylord). Péan, under the name of bone aneurism, has described two telangiectatic tumors of the face with erosion of the bone, but these can hardly be called aneurisms. The blood tumors of the vertex of the skull, which may be considered as varices, have either a congenital, a traumatic, or possibly a syphilitic origin. They are compressible tumors of the cranium, more marked when the patient is lying down, and consist of a thin-walled sac which connects with one of the sinuses by an artificial opening or, more commonly, by an anomalous vein. In their growth these blood tumors cause absorption of the bone from pressure.

Pathology.—Two forms of blood tumors have been described—a central and a peripheral. The central ones present the appearance of a cavity situated at either end of one of the long bones, usually the lower end of the femur or the upper end of the tibia. This cavity is lined with dense fibrous tissue and is filled with blood-clot and detritus. Vessels are seen opening directly into the cavity, as would be expected in both sarcoma and aneurism. The subperiosteal form of blood tumor is also described as a cavity which contains blood and detritus and is covered with dense fibrous membrane, often partly ossified, from which radiate spicules of bone. Microscopically, the cavity is found to be lined with fibrous tissues, and the surrounding bone shows inflammatory changes. There are also often present giant cells, which those who maintain the existence of such a condition as a bone aneurism pronounce not to be of a sarcomatous nature.

Symptoms.—The symptoms are the same as those of a giant-cell central sarcoma or endothelioma, and consist of some disability and pain followed by the development of a tumor. Pathological fracture and crackling on pressure are sometimes found. Expansile pulsation, such as is seen in aneurism, is present, and there may be heard a bruit which ceases when pressure is made on the main artery of the limb. Diminution in size and also questionable cures have been reported following ligation of this artery.

Treatment, etc.—See Giant-cell Sarcoma.

SARCOMA.

Among the tumors of a sarcomatous nature those which originate in bone constitute the largest and most important group; and, although the disease has been recognized for many years, the opinions expressed by the various observers still differ widely as to the proper classification and treatment of the condition. There are a few well-recognized types of bone sarcoma, but most of the tumors contain many different tissues. The pathological classification, therefore, is confusing and the various names that have been applied are very loosely used in designating the different forms. It is important that the sur-

geon should be able to distinguish, before operation, between certain of these forms, for their malignancy varies greatly, and, besides, the radical operation justified in one type is not necessary in another. The growths are usually single, but occasionally they are multiple, and they have a predilection for certain bones, although any bone in the body may be attacked. When multiple, they are usually associated with some bone disease, as osteomalacia, Paget's disease, etc.; but multiplicity is a characteristic of certain growths that are usually classified with the sarcomata, namely, multiple myeloma and endothelioma. The sexes are about equally affected, although men are slightly more prone to the disease than women.

Sarcoma is usually seen in young adults, more frequently in the second and third decades; that is, during the latter part of the formation of the bony skeleton. Thus, in Reinhardt's collection of fifty-four cases of sarcoma of the long bones, more than one-half occurred in patients between fifteen and twenty years of age. Bone sarcoma, however, is seen both in old age and in infancy, cases having been reported as occurring during fœtal life. The age at which the different forms of sarcoma appear also varies, the medullary giant-cell type being seen somewhat later in life—between twenty-five and forty—than the round- or spindle-cell variety, and the growths occurring in early life are, as a rule, more malignant than those seen in the aged.

The relation of trauma to sarcoma is little understood. Virchow and many of the older writers give it an important place in the etiology, and it is a fact that in many cases a more or less clear history of a blow may be obtained, this being given as a reason why the tumors are more common in the male. It is extremely doubtful, however, whether any active boy ever reaches the age of twenty without having received more or less violent traumata on almost every portion of his body, while sarcoma, on the other hand, is comparatively rare. Trauma may first call attention to a small pre-existing tumor or may stimulate its growth; or—as the question is usually put as a leading one by the physician—the patient may at once think of a blow which he had received at some previous time but which he would otherwise have completely forgotten, as happens in the case of most small injuries. The knee is said to be the commonest seat of sarcoma on account of its liability to trauma, but it certainly receives no more blows than does the elbow or the ankle, while sarcoma of the finger or toes, which parts are constantly receiving injuries, is almost unknown. Reinhardt, on careful questioning, was able to obtain a distinct history of trauma in only nine cases (16.6 per cent).

Heredity, occupation, syphilis, and tuberculosis bear no relation to the disease.

The long bones of the extremities and the jaws are the most common seats of sarcoma, the frequency with which the various bones are attacked being well shown in the collection of 691 cases made by Pollosson and Bérard*:—

*Cong. de Chir., 1899.

Femur	112	Sacrum	6
Tibia	80	Scapula	14
Humerus	74	Jaw	227
Radius	36	Head	23
Ulna	14	Thorax	20
Fibula	20	Hand	19
Ilium	17	Foot	29

The number of cases occurring in the hands and feet in this table is somewhat greater than is generally given, sarcoma of the hands and feet being usually considered very rare. Not only are the individual bones affected with varying frequency, but it has also been noted that certain forms of sarcoma are somewhat more common in certain bones than are other varieties. Thus, for example, the osteoid round- or spindle-cell variety is more common in the lower end of the femur or upper end of the humerus than the giant-cell, while the latter is more common in the upper end of the tibia, the lower jaw, and the lower end of the radius or the ulna.

The tumors appear with greater frequency in the long bones near the epiphyseal ends of the diaphysis, the medullary giant-cell form rarely being seen in any other position. The round-cell variety, although usually seen near the epiphysis, is the commonest form found in the shaft. The lower end of the femur and the upper end of the tibia are the commonest seats, but the reasons for this are not clear. It has been suggested that the bone in this vicinity is in an unstable condition, as these epiphyses are among the last to unite with the shaft, being present as separate objects until the twenty-first or even as late as the twenty-fourth year, according to different observers. This is no later, however, than has been observed in the case of the epiphyses of certain of the flat bones—*e. g.*, the sternum, the pelvis, and the lower end of the radius.

Sarcomata of the bone may be divided into two main classes: (1) periosteal and (2) medullary or central. Reinhardt makes a third group of tumors in which it is impossible to say—at least at the time when the growth is first seen—whether it arose in the periosteum or in the medulla, the process early involving both parts of the bone—a statement which is particularly true in certain of the flat bones, as the scapula.

Considerable difference of opinion exists as to the relative frequency with which the medullary and the periosteal varieties occur. Reinhardt * in 54 cases found 15 periosteal, 30 medullary, and 9 involving both. Gross † concluded that the medullary were more common by eighteen per cent; while Nasse, ‡ on the other hand, in his collection found 19 medullary to 21 periosteal.

Under the heading of "Periosteal Sarcomata" is included a group of tumors to which the name "Parosteal" has been applied. These arise from the outer layers

* Deut. Zeit. f. Chir., 1897–98, xlvii., 523.

† American Journal of the Medical Sciences, 1879. ‡ Arch. f. klin. Chir., 1889, xxxix., 889.

of the periosteum or the surrounding tissue, and, while not attached to the bone at first, soon become so, after which they act as periosteal sarcomata.

Tumors of central origin present two more or less distinct types, which are of importance as regards prognosis and treatment. In one form the cortical bone is absorbed and the growth presents an encapsulated appearance, while in the other the process extends by infiltration, and no sharp line can be drawn between the tumor and the normal bone. The cortical bone in this latter form is usually thickened. However much the tumor invades the soft parts, the cortical bone, or the medulla, it is usually limited by the epiphyseal cartilage; and in sarcomata that develop in the epiphysis the articular cartilage usually remains intact; in other words, the tumor cells are unable to break through actively growing cartilage, although cases in which this has occurred have been reported. Changes in the joint are usually of a secondary nature.

Classification.

The sarcomata are best divided into the groups given below, it being understood that the types vary to a greater or less extent, and that no hard and fast rule can be made:

Periosteal.	Medullary.
Spindle-cell.	Round-cell.
Round-cell.	Spindle-cell.
Osteoid.	Giant-cell.

The round- and spindle-cell sarcomata constitute fairly constant types, as does also the giant-cell medullary sarcoma; but the osteoid sarcoma of Virchow varies greatly and it is necessary to employ the adjectives chondro-, fibro-, lipo-, myxo-, etc., in describing the actual characteristics of a given tumor.

Osteoid Sarcoma.—This is probably the most common type of sarcoma, and, as a rule, it is very malignant, although certain of the rarer hard forms are comparatively benign. The tumor arises from the inner layers of the periosteum and is characterized by the presence of osteoid trabeculæ in which calcium salts may be later deposited, and which usually become converted into true bone in the older portions of the growth during the course of the disease. This osteoid tissue, which is somewhat analogous to that seen in the process of bone regeneration in a callus occurring after fracture, forms the ground substance of the tumor. The cellular elements vary, round or spindle cells being commonly seen, but the character and the cell richness may vary greatly in different portions of the same tumor. (Fig. 192.) Some are distinctly fibrous, while others are sarcomatous, or the greater part of the tumor may be chondromatous, with a small area of round-cell sarcoma. It will therefore be seen that the term "osteoid sarcoma," as used by the German observers, comprises a large class of tumors; for, although certain of these form a very definite group, osteoid

tissue may be found in nearly all forms of bone sarcoma or fibroma. The term "osteo-sarcoma" is also often applied to these growths when the osteoid tissue has formed true bone, but it is best to use it to designate the whole class of sarcomata of bone.

Osteoid sarcomata are seen in the early stages as slightly raised fusiform swellings under the periosteum. As they grow, the cortex of the bone becomes roughened and the tumor cells extend through the canals into the medulla, where a similar but smaller growth is formed early. Similar changes are observed when a sarcoma develops in one of the flat bones, the marrow spaces being involved shortly after the periosteum. A characteristic of the tumor

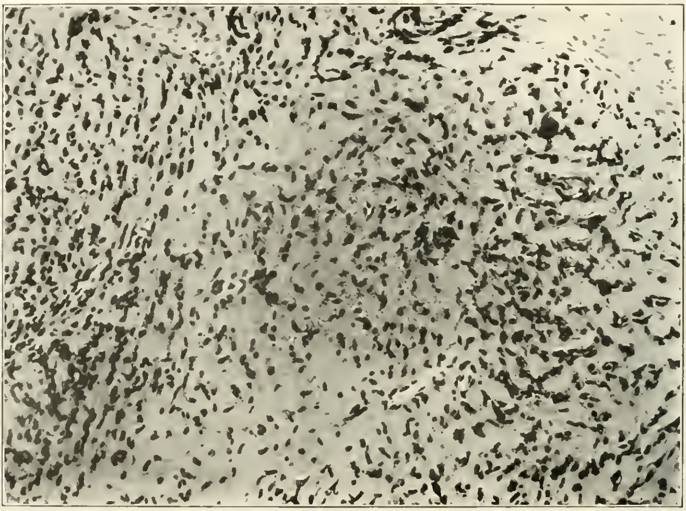


Fig. 192.—Photomicrograph of an Osteoid Sarcoma of the Fibula. The cells are lying between the osteoid trabeculæ. (Original.)

is that, although it may be both medullary and periosteal, the thickness of the cortex is not changed. Examination in advanced cases shows arising from the shaft of the bone delicate needles and trabeculæ, often fan-shaped, which at their base, in a macerated specimen, are seen to be composed of ivory-like bone. The tumors are usually surrounded by a capsule of dense fibrous tissue derived from the outer layers of the periosteum, but there may be infiltration of the adjacent soft parts. Immediately beneath the capsule the growth is very cellular and presents many hemorrhagic cysts and necrotic areas, but shows little osteoid or bony tissue, although here and there small calcified nodules may be found. At a greater depth osteoid trabeculæ are seen, and

as the shaft is approached these trabeculæ gradually become solid bone, the change taking place by the deposition of calcium salts in their centres.

The osteoid chondroma possesses similar characteristics, the ground-work being formed of cartilaginous trabeculæ which may later become bone. These tumors present a structure so closely resembling that which is observed in the process of repair following a fracture that they are often termed "malignant callus-tumors."

Both of these tumors are seen most commonly near the epiphyseal ends of the long bones, the osteoid chondroma being practically never seen elsewhere;

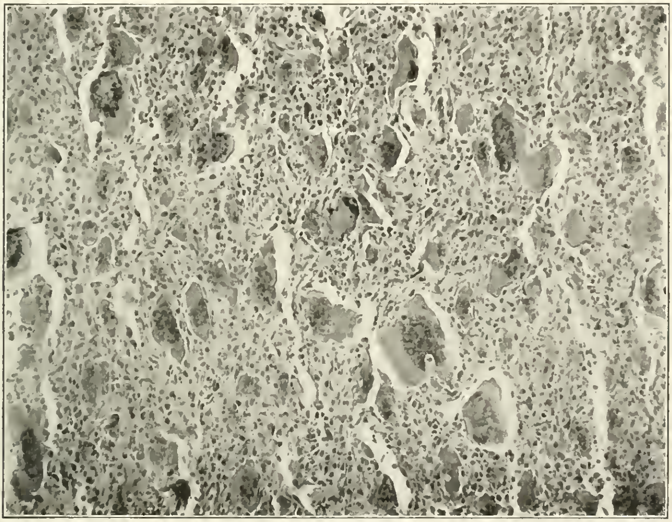


FIG. 193.—Photomicrograph of a Giant-cell Sarcoma of the Gum (Epulis). (Original.)

but the osteoid sarcoma is also seen in the jaw, on the skull, and on the flat bones. They are usually single, but may be multiple.

Giant-cell Sarcoma.—Giant cells may be seen in any form of sarcoma, but the tumor to which the name is commonly applied and in which they occur in greatest numbers is the myelogenous giant-cell sarcoma, which is seen almost exclusively in the epiphyseal ends of the long bones or in the jaws. When this variety occurs in osteomalacia, however, the tumor is often seen in the diaphysis. Such tumors grow slowly, gradually distending the end of the bone and at the same time thinning the cortex and destroying the medulla (spina ventosa), and, if left untreated, they attain enormous dimensions, finally breaking through and infiltrating the soft parts. The cortex may be entirely destroyed, but

there is always some new bone formation from the periosteum. The tumors are extremely prone to degeneration and in many cases it is almost impossible to make the diagnosis, even with the microscope, owing to the fact that the growths consist only of a soft, hemorrhagic, necrotic mass. On section, when the tumor is not necrotic, it appears soft and of a dark red color; the aspect of the cut surface being not unlike that of a section of the spleen. Microscopically, the tissue of these growths is composed of a loose ground substance of spindle or round cells, among which are scattered large numbers of multinuclear giant cells similar to those seen in the bone marrow. (Fig. 193.) The tissue is extremely vascular, and hemorrhagic areas are common. A special variety of giant-cell sarcoma, similar to that which develops in the central part of the bone, sometimes springs from the periosteum of the alveolar process (epulis). It is, however, less prone to degenerative changes and usually shows some ossification or calcification.

Spindle- and Round-cell Sarcomata.—Spindle and round-cell sarcomata of bone are similar to those of the same type which develop in the soft parts; they are among the most malignant of bone tumors. (Fig. 194.) In the course of their growth they gradually destroy the bone, and at the same time no new formation of bone takes place. Pathological fracture is, therefore, a common occurrence in the history of these tumors.

Fig. 194.—Round-cell Sarcoma of the First Metacarpal Bone. (Massachusetts General Hospital.)

The spindle-cell sarcoma occurs with about equal frequency under the periosteum and in the medulla, while the round-cell variety is more apt to be centrally situated and is rarely encapsulated. On section, the growths are found to be soft and of a reddish or grayish color, and, like the other forms, they are commonly seen at the epiphyseal ends of the long bones, although the round-cell variety is not infrequently observed on the shaft. The latter variety is also more apt to be multiple than is any other type.

Symptoms.

The symptoms of sarcoma vary with the position of the growth, but similar tumors in the same position may cause an entirely different chain of symptoms. The chief symptoms are pain, tumor, cachexia, and disability caused by destruction of the part or through pressure on or involvement of neighboring structures.

Central Sarcoma of the Long Bones.—In the central form of sarcoma pain is the first symptom which calls attention to the condition in from forty

to sixty per cent of the cases, and it is usually constant, dull and aching in character, but may be sharp and intermittent. This pain is referred, in a large number of cases, directly to the joint, and may closely simulate some form of arthritis, thus leading to a faulty diagnosis, unless a careful examination is made. Unlike arthritic pain, however, it is not increased by motion, is often worse at night when the limb is at rest, and it is rarely associated with limitation of motion except in the later stages. Pain is present in nearly all the cases at some time during the course of the disease, and varies somewhat with the type of tumor, being more marked in the rapidly growing round-cell sarcoma than in the slow-growing giant-cell variety.

In the central form of sarcoma the presence of a perceptible tumor is not recognized at an early stage of the disease, the slight increase in the size of the limb remaining unnoticed by the patient for some time. In a few cases pain and tumor are noticed simultaneously, but the former is usually the first symptom observed by the patient. The tumor varies in shape and consistency, but is usually fusiform or globular and hard. In the latter stages of the disease the tumor may be elastic or fluctuating in places, owing to the degeneration which has taken place in its substance. The cortex of the bone may also undergo destruction, this being true chiefly of the giant-cell type. Parchment-like crepitation is sometimes present. A certain number of these tumors, on account of their vascularity, have a distinct pulsation, and on auscultation a bruit may be heard. This fact led the older writers to believe that these tumors were aneurisms. The symptoms here enumerated are most common in the soft, rapidly growing forms—the round-cell and the giant-cell varieties and the endothelioma. The rate of growth varies, the soft malignant tumors growing more rapidly than the hard or than the giant-cell variety. Occasionally there may be a rise of temperature of the neighboring parts due to the increased blood supply, but this is not constant, and is of little value in diagnosis. Enlarged vessels in the skin may be seen, but they are rare in the early stages of central sarcoma. They are caused by pressure and by involvement of the deeper vessels, and are of no particular diagnostic value. Ulceration rarely occurs. As the disease progresses, deformity becomes more marked, and there is muscular atrophy of the affected limb, with general cachexia, disability, etc.—symptoms which are observed in the course of any malignant growth.

In the central sarcoma, particularly in the round-cell variety, pathological fracture is extremely common, and is due to the destruction of the bone. Gross speaks of it as occurring in forty-four per cent of the cases; and, although this is a somewhat higher percentage than would be noted at the present day, it is easy to see—if the growths were left untreated—why it should occur in nearly every case. In some, fracture, resulting from slight violence or occurring spontaneously, is the first symptom that calls attention to the condition, which may be overlooked if a radiograph is not taken. It is probably for this reason

that the statement was formerly made that a sarcoma often develops at the seat of the fracture, the inference being, in many of the cases, that the tumor existed at the time of fracture and was stimulated by it into more rapid growth.

Periosteal Sarcoma.—The symptoms, in the periosteal variety, are much the same as those observed in central sarcoma, but they differ in degree. The presence of a tumor is usually the first symptom, and, owing to the position of the growth, it is recognized early. The tumor itself is fusiform in shape and regular in outline. It is firm, but may be elastic; it has not the bony hardness of central growths, and its smooth regular outlines serve to differentiate it from the benign bone tumors. Pain is present, at some time during the disease, in nearly all the cases, but is not as early a symptom as it is in central sarcoma; it is also more apt to be neuralgic in character than of a dull nature. From the character of the pain and the position of the tumor, it rarely happens that the disease is confused with an affection of the joint. A local rise of temperature is more common than in the central variety, as is also the presence of dilated superficial veins and of œdema of the extremity from pressure on the deep vessels. Tenderness may be present and, in rare instances, ulceration. The lymph nodes are more often enlarged in the periosteal than in the central variety, but this enlargement is usually due to inflammatory changes and not to an invasion of the new growth.

Diagnosis.

The diagnosis of sarcoma, particularly when it was seated in one of the long bones and before the days of the *x*-ray, was difficult, and in the early stages impossible; but at the present time it is a comparatively easy matter. It should be a rule, not only when sarcoma is suspected, but also in any case of joint or bone disease, to have a radiograph taken, this being in many cases an absolute guide; but the plates should be passed upon by a man who is accustomed to interpreting them, as it is easy for one who is not an adept, to make errors.

The *x*-ray negative of a typical periosteal sarcoma, when not in an advanced stage, shows the periosteum at the edges of the tumor dissected up and becoming gradually lost in the soft parts. Under the periosteum and in the substance of the tumor fine trabeculæ of bone can be seen more or less clearly, the degree of distinctness depending on the type of growth. In some cases they are very indistinct and give to the negative a cloudy appearance. The outline of the tumor is also apt to be indistinct and to blend with the soft parts. The cortex under the periosteum appears rough, and in the osteoid form it is rarely thinned. In the medulla there may be a dark area indicating involvement. In the advanced stages one may distinguish dark areas representing cartilage or cysts, and light areas of bone or calcification. In the round- or spindle-cell subperiosteal form the amount of newly formed bone is small, and the cortex is

rarefied or completely destroyed; while above or below the growth there may be thickening due to the formation of new bone (Fig. 169).

The typical giant-cell sarcoma appears, in the radiograph, as a clear area situated at the end of the bone and looking not unlike a cyst, but the outlines are as a rule not as clearly marked, and, in many cases, fine trabeculæ of bone extend across it. In the later stages there is distinct swelling, with thinning of

FIG. 195.—Small Round-cell Sarcoma of the Ulna. Note the bone destruction and pathological fracture. (Massachusetts General Hospital.)

the cortex, the tumor as before appearing as a cavity with irregular walls, which may be partly absent when the growth has extended through into the soft parts (Figs. 197 and 203).

Central round- and spindle-cell sarcomata do not appear as well-defined encapsulated tumors. (Fig. 195.) The bone is gradually absorbed and has a worm-eaten appearance, while in the later stages it may be entirely replaced by the tumor.

It will thus be seen that, with the aid of the radiograph, which reveals the normal appearance of the cartilage, joint affections such as the various forms of arthritis are easily ruled out. Syphilitic joints (Charcot's joints) show complete disorganization, with almost entire destruction of the ends of both bones. Syphilis in some of the other forms is more difficult to exclude. The typical gumma of the bone appears in the radiograph as a dense hard tumor, without structure, usually situated beneath the periosteum. There are often several gummata and they are situated on the shaft; they occur only rarely near the epiphyses. Small multiple cysts may occur in syphilis, and in the radiograph they may resemble in some degree giant-cell sarcomata, but they are accompanied by an irregular cortex periostitis and by other signs of an inflammatory process. Osteomyelitis, with an accompanying sequestrum or a bone abscess, may furnish a radiographic picture like that of sarcoma, but these conditions are accompanied by inflammatory changes in the bone periosteum and soft parts, and, besides, the clinical history is usually suggestive.

Endostoma closely resembles central giant-cell sarcoma, but, instead of appearing as a hole, the tumor is, if anything, more dense than the normal bone. Clinically, the two conditions cannot be distinguished.

In many cases a chondroma of bone is difficult to differentiate from a sarcoma, and, on account of the liability of these tumors to undergo retrograde changes, many of them must be classified as malignant growths. Cartilaginous growths appear in the radiograph as poorly defined tumors, the cartilage itself casting no shadow. The bone is more or less destroyed, but shadows caused by calcified areas are often seen in the tumor. Clinically, the association with other skeletal defects is often an aid in the diagnosis. Cysts, in reality a form of chondroma, resemble giant-cell sarcoma closely, but in the typical form they present a smooth lining membrane and are seen somewhat earlier in life. (See Fig. 191.)

Swelling in the neighborhood of the joints, in rickets and allied diseases, is easily differentiated by the other symptoms.

A piece of the tumor should never be removed at a preliminary operation for the purpose of diagnosis, as this is liable to disseminate the disease. In case of doubt, a pathological examination may be made at the time of the operation, the surgeon removing a small portion of the tumor and waiting for the pathological report before proceeding with the operation.

Treatment.

The treatment of sarcoma of the long bones is narrowed practically to the choice of operation in a given case, and of these operative measures there are three: (1) excision and curetting; (2) resection of the part of the bone involved; and (3) amputation or disarticulation.

Amputation is the operation usually employed in all cases of sarcoma, but in some forms it is unnecessary. For many years resection or excision has been advocated by certain men, and at the present time this is coming more and more into vogue, and for certain forms it is already the recognized treatment. Some go so far as to say that amputation is never justifiable in any form of sarcoma, giving as a reason that, if there are not lung metastases at the time of the operation, the tumor will come back only locally, if at all; while, if metastases are already present, it is apparent that no hope can be entertained of effecting a cure by means of an operation, and the patient is better off for the remainder of his life with the more or less useful limb obtainable after excision.

Others consider a cure in any of the malignant forms of tumor as hopeless, and they operate only as a palliative measure. Mikulicz believes that excision or resection is the operation of choice in all forms of sarcoma, and he gives reports of seven cases, but his results are not convincing. Probably at some time during its early development sarcoma is purely local, but unfortunately it is rarely seen or recognized during this period.

The treatment naturally varies with the type of growth, its size, and its situation, it being necessary at the same time to take into consideration the probable functional result obtainable. In all cases the consent of the patient to amputation should be obtained before any operative interference is undertaken; and the actual measures to be adopted should be determined by the conditions found when the tumor is exposed, even when the diagnosis obtained by means of the x-ray is fairly positive. It is also best, when possible, to have a pathologist verify the diagnosis with the microscope, although the gross appearance of sarcoma is quite characteristic.

The operation of amputation is done in the same manner as it usually is for other causes. When it is performed for a periosteal growth it is the custom to remove the whole of the bone involved, if the femur, by disarticulation at the hip joint, or to amputate through the thigh if the tibia or the fibula is the bone affected. If amputation through the diseased bone is done, the growths may come back locally in what appeared to be, at the time of the operation, normal bone.

In excision the operator must be guided by the circumstances present in each individual case, and no rules can be laid down. In general, when this operation is performed for a medullary sarcoma of small size, which has not involved the periosteum, it may be done subperiosteally by the method described by Nichols, but this is rarely possible. In most cases it is necessary to remove the bone and periosteum with perhaps some of the adjacent soft parts.

When the growth alone is excised, the operation should be done with a mallet and chisel, a hand gouge and a curette, and a considerable amount of normal bone should be removed with it. This operation is applicable only to the more benign central tumors that are localized and encapsulated. Excision

or resection should not be attempted in any case where the growth is large, the soft parts infiltrated, or the chance of a good functional result poor.

As the lymph nodes in sarcoma are rarely affected unless the growth has attained a large size or is in close proximity to them, it is unnecessary to undertake a long dissecting operation for their removal.

Central Sarcoma.—In the central giant-cell sarcoma of small or moderate size, excision or resection is the operation of choice, as the growth is essentially benign and rarely forms metastases. In the case of a sarcoma of the upper extremity resection should be done, inasmuch as this operation is likely to be followed by a good functional result. If the head of the humerus is excised, most of the motions of the arm can be performed, and this is also true when the lower end of the radius or ulna—a common seat of giant-cell sarcoma—is removed, the patient in all cases getting a more or less useful hand. In the case of a tumor of the lower extremity—*e.g.*, in the region of the knee or head of the femur—resection at best will give a very short leg with a stiff joint, so that in this position curetting, in the case of a giant-cell sarcoma, should be advised instead of resection, and amputation performed later if necessary, with the full consent of the patient and with the understanding that the chances of obtaining a cure by this method are no more than even, and that there is at least a possibility that metastases may take place.

Fig. 196.—Periosteal Osteoid Sarcoma of the Head of the Tibia. (Massachusetts General Hospital.)

In the spindle-cell type of central sarcoma—which is, next to the giant-cell variety, the least malignant—the same argument applies, and resection or excision should be preferred to amputation in the case of small non-infiltrating growths; and yet, as a matter of fact, the latter operation usually proves to be necessary.

The round-cell central sarcomata are more malignant than the other varieties and are less likely to be encapsulated; consequently, in these, amputation is the operation of choice.

Periosteal Sarcoma.—In periosteal sarcoma, which is much more ma-

lignant than the central variety, amputation, with the removal of the whole bone, is the operation to be advised in all the forms, with the possible exception of a small sarcoma of the lower end of the femur, in which case a high amputation may be done in preference to disarticulation at the hip joint, as after the

Fig. 197.—Giant-cell Medullary Sarcoma of the Lower End of the Ulna. Excision. No recurrence in five years. (Massachusetts General Hospital.)

latter it is almost impossible to fit an artificial leg. If the growth has attained considerable size, however, the functional result should not be taken into consideration. The results obtained by any operation are very unsatisfactory. The treatment will be considered more fully under the heading of "Sarcoma of Special Bones."

Treatment by x-Rays.

Much has been said of late about the curative effects of x-rays on different forms of malignant growths, both sarcoma and carcinoma; but, whatever value this mode of treatment may have in other forms, it should never be used primarily, or as a pre-operative measure, in sarcomata of bone. The cases of reported cures from x-rays have been followed for only a short time, and in those cases which have been traced carefully the disease has almost invariably recurred. It is a well-known fact, also, that sarcomata may fluctuate in size and even disappear spontaneously. Of the sixty-eight cases of sarcoma collected by Coley* which had been treated by the x-ray, in only five had the growth disappeared, and in these cases it recurred after the lapse of a few months. In one of the latter, however, the disease again disappeared under treatment with x-rays and toxins. The x-ray treatment may be used in inoperable cases, as it allays the pain and may retard the growth. It may also be used as a prophylactic after operation, but its value, on the whole, is extremely doubtful.

Toxin Treatment.

The value of the toxin treatment, as advocated by Coley,† is problematical, and it certainly should never be employed when an operation is possible. It may be tried in inoperable cases or as a prophylactic after operation. From 0.2 to 0.5 cubic centimetre of the mixed toxins of the streptococcus and Bacillus prodigiosus should be given subcutaneously every day, or until some slight reaction occurs, as shown by a rise of temperature, malaise, etc.

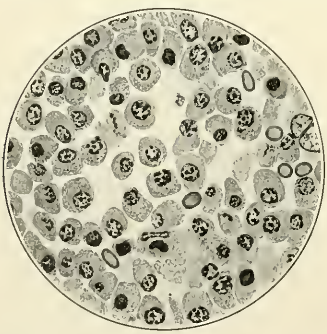


Fig. 198. Multiple Myeloma. (Case of Dr. James H. Wright.) The type of the cells is well shown. In portions of the tumor, where the cells are more closely packed, they are of polyhedral shape. (Oil immersion.)

In support of the value of the toxins should be mentioned the results obtained by the older surgeons, represented by Gross, in their operations on sarcomata. These results, which were obtained at a time when sepsis was the rule, are better than those secured at the present time when sepsis is the exception. Some have therefore suggested the plan of infecting the stump, in cases of periosteal sarcoma, at the time of operation; the danger, when the sepsis is properly treated, being very slight (Wyeth).

*Annals of Surgery, 1905, xlii., 161. †*Op. cit.*, March, 1907.

Results of Treatment.

The operative results obtained in sarcoma of the long bones are, as a whole, very discouraging. They vary, however, in the different forms of sarcoma, and it is unfortunate that, in certain collections of statistics, the exact type of tumor is not given.

The periosteal growths are much more malignant than the central, and of the former the round- and spindle-cell varieties are more so than the osteoid; that is, the soft, rapidly growing, vascular tumors, as is the case in all malignant growths, are more fatal than the slow-growing varieties. Most of the cases die of metastases within a year from the time of operation, and, unlike what occurs in carcinoma, patients who live beyond three years without manifesting any evidence of a return of the disease cannot be called cured, for it is not uncommon to have metastases first show themselves at the end of four, six, or even ten years. These commonly occur in the lungs, the cells being carried by the blood-vessels. They are rarely conveyed by way of the lymph channels, and the lymph nodes are therefore not often involved. When the nodes are enlarged, this change is usually due to an inflammatory reaction. Next to the lungs, the abdominal viscera are the most common seats of metastases. Local recurrence is comparatively rare if the operation has been thoroughly done, but it occurs most often when amputation has been performed through the diseased bone. Gross' statistics as to recurrence and metastases, based on 165 cases, are as follows:

	Adjacent Tissue Involved. Per cent.	Local Recurrence. Per cent.	Glandular Recurrence. Per cent.	Generalization. Per cent.
Periosteal, spindle-cell	44	60	0	100
" round-cell	50	50	7.69	$66\frac{2}{3}$
" osteoid	40	41	6.25	$65\frac{2}{3}$
Central, spindle-cell	16	20	0	$23\frac{1}{3}$
" round-cell	66	25	8.33	$33\frac{1}{3}$
" giant-cell	12	8	0	22.72

Of the central sarcomata the giant-cell species is almost a benign tumor, although occasionally it forms metastases. The central round- and spindle-cell types, although considerably more malignant, are less so than the same tumors when arising under the periosteum. Bloodgood has reported seven cases of giant-cell sarcoma with no deaths from metastases, and although two returned locally they were easily removed. Nasse has reported eight similar ones, but several of the cases in both these series had been observed for only a short time after operation.

SARCOMA OF SPECIAL BONES.

Skull.—Sarcomata of the head, aside from those occurring about the jaw, are comparatively rare. They occur usually on the anterior portion, in the neighborhood of the orbit, the periosteal variety being more common and the growths usually being very vascular. The multiple forms often affect the vault of the cranium. They are usually of rapid growth, infiltrate the surrounding soft parts and the accessory sinuses early, and on account of their character and position are very malignant. Most of these growths are inoperable, but, if an operation is attempted, it must be devised for the individual case.

Fig. 199.—Round-cell Periosteal Sarcoma of the Jaw. (Massachusetts General Hospital.)

Jaws.—Sarcoma of the jaw is common and is usually seen somewhat later in life than is true of sarcomata of the long bones. The sexes are equally affected. In the upper jaw sarcoma is less common than in the lower, and here it is often impossible to determine whether it is of periosteal or of central origin. When seen clinically the tumor is usually of considerable size relatively to the part affected, and partial or complete excision is indicated, the particular operation to be employed depending on the size and type of the growth (Fig. 199).

In the lower jaw the central variety is seen more often than the periosteal, the proportion—if epulis be disregarded—being about 5 to 3. The body of the jaw is the usual seat, the tumors being rare on the ramus, and the round- and spindle-cell are the common periosteal forms. These are very malignant, infiltrating the soft parts and forming metastases in the lungs early. Excision of one-half of the jaw is the operation of choice, but the results are poor. Out of 11 cases 8 died of rapid recurrence and 2 of metastases, the other being alive at the end of two and one-half years. (Butlin.*)

The central sarcomata of the lower jaw, as is true of this variety in other parts of the body, are much less malignant, but care must be taken not to confuse certain forms of odontoma with sarcoma. A few may be removed without resection, but in the large majority of the cases this is impracticable, and partial excision, subperiosteal if possible, is necessary. The results are good,

* "The Operative Treatment of Malignant Disease," 1900.

particularly in the giant-cell form. In but two out of fifteen cases was there a recurrence (Butlin), but both of these died.

Epulis.—This is a term used to designate a tumor that springs from the gums. It is usually classed with the sarcomata, but is benign. The etiology is obscure, but the disease has a distinct relation to irritation about the teeth. It is seen in both the upper and the lower jaw—in the latter about twice as often as in the former. It develops on the alveolar border, usually at the base of a carious tooth, or in the socket of one that has been extracted. It is not unusual, however, to see it between two comparatively healthy teeth, and in this case there is generally a collection of tartar around the base of the tooth. It is more often seen in young adults between twenty and thirty, and is more common in the female. It is rarely multiple. (See also the article on Surgical Diseases and Wounds of the Jaws, in a later volume.)

Pathology.—These tumors are usually seen in the region of the bicuspids, the first molars, or the incisors, and as they grow they project outward, forming soft or hard, smooth purplish masses. If they are allowed to attain a large size they displace the adjacent teeth and cause at times absorption of the alveolar process. They arise, according to most authorities, from the periosteum and are covered with mucous membrane which may be ulcerated. There are two main types, the fibrous and the giant-cell, either of which may be sessile or pedunculated. The fibrous variety is firm, and on section displays a reddish-gray color. It may contain calcified areas or spicules of new bone. Microscopically, it is vascular, more or less cellular, and composed of spindle cells and a few round cells. The giant-cell type is softer, of a deeper color, often telangiectatic, and microscopically it has the general appearance of a giant-cell sarcoma. Between the two types a great variety of intermediate forms may be seen. (Fig. 193.)

Symptoms.—Symptoms other than those caused by the presence of the growth are unusual. There may be neuralgic pain, and a small amount of bleeding is not uncommon. Interference with mastication may occur, and, if ulceration is present, the breath is likely to be fetid. Examination shows the presence of the growth, which rarely exceeds one inch in diameter and is situated on the outer side of the alveolus, usually near a diseased tooth.

Diagnosis.—The diagnosis in most cases is simple, the position and appearance of the tumor being characteristic. It may be distinguished from carcinoma by the facts that the latter is seen in older people, is ulcerated from the first, and has an entirely different appearance. Exuberant granulation tissue in a tooth socket may closely resemble epulis.

Treatment.—Operative treatment is best. Palliative treatment consists of cauterizing with acids or with the galvano-cautery, but this method is slow and the results are not sure. Operative treatment consists of removal of the growth with a portion of the alveolar process. If, in the giant-cell type, the alveolar

process is not removed, recurrence is the rule. The fibrous type does not tend to recur, but a differential clinical diagnosis is usually impossible. The ultimate deformity is slight after operation and the results are satisfactory.

Prognosis.—The prognosis is good, epulis never being fatal. When recurrences take place they are small, local, and easily removed, but they are uncommon if the operation has been sufficiently extensive.

Sternum.—Sarcoma of the sternum, as a primary tumor, is rare, and, unless superficially located and of small size, it is not amenable to treatment. In a collection of eleven cases of excision of the sternum there were four deaths, that were caused by hemorrhage, pneumothorax, and by shock, and the final results when known were bad.

Ribs.—In the ribs sarcomata are comparatively common, but probably not more than forty per cent are operable, and in many instances it is impossible to say how much of the thoracic cavity is involved in the growth. The prognosis varies with the type of growth, its size, and the organs involved, and although many of the cases are hopeless, some brilliant results have been obtained. (Plate XX, Fig. 1.)

The chief danger in operating on any of these growths is that of opening the pleural cavity, an event which is usually followed by collapse of the lung, dyspnœa, rapid pulse, severe shock, and subsequent death, the symptoms varying with the size of the opening. In not a few cases the act of opening the pleural cavity is not followed by any untoward symptoms, and in some of these cases, but certainly not in all, there are probably, in the neighborhood of the tumor, adhesions which keep the lung from collapsing. When symptoms do occur they usually immediately cease on closure of the opening. It is possible to remove some of the sarcomata of the ribs without entering the pleural cavity. In removing the tumor it is important, if any hope of effecting a cure is entertained, to make the incision, as in the case of malignant tumors in other parts of the body, at a good distance from the growth and in healthy tissue. In a few instances portions of the diaphragm and pericardium have been removed successfully.

Several procedures have been devised for preventing the lung from collapsing when the pleural cavity is opened. The maintenance of pressure in the lung by forcing air through a tracheotomy tube is usually followed by emphysema or pneumonia. This is a procedure, therefore, which must be rejected. Sauerbruck* has recently performed several successful operations on the thoracic viscera of animals, in a pneumatic cabinet which was large enough to contain the surgeon, his assistant, and the patient, and in which the air was partially exhausted. The head of the patient projects through one side of the cabinet, and the abdomen and legs are contained in a rubber bag, also connecting with the outside air and fastened tightly around the waist. The pleural

*Arch. f. klin. Chir., 1904, lxxii., 976.

EXPLANATION OF PLATE XXIII.

Fig. 1.—A section of a rib from a case of multiple myeloma, enlarged one-fifth.

The specimen consisted of a shell of bone covered with periosteum. The cortex varied in thickness, but was everywhere thin and in places entirely wanting. The medulla was replaced by the new growth, which was extremely soft and varied from a light gray to a dark red in color. In places a few fine spicules of bone extended in from the cortex.

Fig. 2.—Small round-cell sarcoma of the head of the tibia, from a young adult.

This specimen illustrates the difficulty of determining the point of origin of certain sarcomata; that is, whether medullary or periosteal. Careful examination showed that this tumor probably arose under the periosteum. The growth occupied the medullary cavity, completely destroyed the cortex, and extended through the skin, pushing the soft parts to one side and not infiltrating them. Infection had taken place and the growth contained several abscess cavities. It was lobulated, with well-marked outlines, and of a grayish-white color.

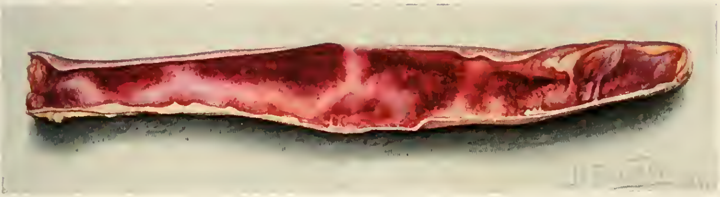


FIG. I.

FIG. 2.

TUMORS OF BONE.

cavity, in this cabinet, can be opened without danger of collapse of the lung, while the pressure is not enough to discommode the operator, being that of about one thousand feet altitude. The few operations which have been performed on human beings in this cabinet have been fairly satisfactory as regards the immediate result, but most of the patients have died a few days later. Brauer has also devised an apparatus of a nature very similar to that of Sauerbruck's cabinet.

Clavicle.—Sarcoma of the clavicle is not common, the central tumors being rarer than the periosteal, and, as is the rule in other bones of the body, less malignant. Norkus* collected from the literature 32 cases in which partial or complete resection had been done, but he failed to report the end results. Butlin† mentions 7 cases, 4 of which died, soon after the operation, of metastases, and the only one known to be alive had been operated upon only a few months before the report of the case. The operation required in this condition consists of partial or complete excision or amputation of the shoulder girdle. Excision, in the periosteal variety of the growth, is very difficult on account of the proximity of important structures and the tendency of the tumor to infiltrate the neighboring tissues. In the central variety excision is easier and in many cases resection is all that is necessary. In both the central and the periosteal varieties it is best, when possible, to allow the sternal end of the clavicle, with the attachment of the sterno-mastoid muscle, to remain intact.

The deformity following operation is considerable. The shoulder falls forward and inward while the scapula becomes prominent. The chest expansion on the affected side is also limited.

Scapula.—Sarcoma of the scapula is also comparatively rare, and in the case of a tumor in this locality it is difficult to note any distinctions between the periosteal and the central forms, all the growths being very malignant. The commonest seat is in the region of the spine or in the lower portion of the body of the bone. Operative interference may be limited to the removal of a portion of the bone, the acromion and the glenoid being left intact; or the entire bone may be removed; or, finally, besides the entire bone, portions of the upper end of the humerus and the clavicle may be removed. Amputation of the upper extremity is also often performed.

The results are poor. In Poinsot's table, where the end results of 25 cases were known, but one could be spoken of as cured. In the collection of 77 cases made by Piqué and Dartigue‡ it was ascertained that 21 had died of a recurrence of the growth, while but 2 could be called cured. The functional results after partial excision are good, and, in complete excision, much better than might be expected.

Humerus.—The head of the humerus is, after the lower end of the femur or

* Beit. zur klin. Chir., 1894, xi., 728.

† "Operative Treatment of Malignant Diseases," 1900. ‡ Rev. d. Chir., 1900, xxi., 437.

upper end of the tibia, the commonest seat of sarcoma. Although tumors of the central variety do occur in this bone, those generally encountered are periosteal, and are extremely malignant, metastases in the lung forming at an early stage and the axillary lymph nodes being often involved (Fig. 200). Although sarcomata involve the lower end of the humerus less frequently than the upper, they are more apt in this situation to be of the central variety and hence more amenable to treatment.

The operations performed in periosteal sarcoma of the head of the humerus are the interscapulo-thoracic amputation and amputation at the shoulder joint. The former, although deforming, is more thorough, and the mortality for the two is about the same. Out of 188 cases of shoulder-girdle amputation done by Berger's method* there were 153 belonging to the period subsequent to 1887; and among this number the mortality was only 7.8 per cent. In the performance of this operation the chief points are to ligate the subclavian vessels as a preliminary measure and to inject a few

FIG. 200.—Chondro-sarcoma of the Humerus. (Massachusetts General Hospital.)

*Jeanbrau et Riché: Rev. d. Chir., 1905, xxxi., 8.

drops of a four-per-cent solution of cocaine into the great nerves before dividing them—this latter for the purpose of preventing shock. The same treatment is also best in central sarcoma of the head of the bone, although, if the growth is small and not particularly malignant, resection may be done. The functional results after resection are fair. For sarcoma in the lower end of the humerus, amputation at the shoulder joint or resection should be performed, according to the type of growth.

Radius and Ulna.—Periosteal sarcoma of these bones is comparatively rare and very malignant, amputation through the humerus being the operation of choice (Fig. 201). Central sarcoma, on the other hand, is not of rare occurrence and is seen in either the upper or the lower end of either bone. Giant-cell sarcoma of the lower end of either of these bones is peculiarly benign, and amputation for this condition is not justifiable. Resection should be done, and amputation later if there should be a recurrence.

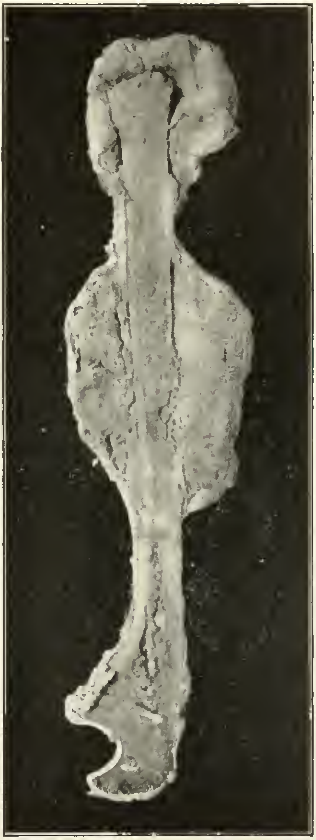


Fig. 201.—Periosteal Round-cell Sarcoma of the Ulna of Three Months' Duration. Metastases found in the lungs. (Warren Museum, Harvard Medical School.)

Pelvis.—Any form of sarcoma may occur in any portion of the pelvis, in which region the disease is usually not amenable to treatment. Interilio-abdominal amputation, as it is termed, has been done for certain of these tumors, and in Keen's* collection of sixteen cases, four survived the operation, but the ultimate results are not given. The operation consists of removing the entire lower extremity with all, or portions of, one-half the pelvis. On account of the high mortality, the extremely poor functional results, and the small chance of effecting a cure, the operation hardly seems justifiable.

The operation of removing portions of the ilium, pubis, or ischium, is not particularly difficult, and good functional results may be obtained after the removal of large portions of these bones. In the only collection of cases which has

* International Clinics, 1904, iv., 127.

been published, the mortality for these operations is absurdly high, seven deaths occurring in eighteen cases (Savariand).

Femur.—The lower end of the femur is the commonest seat of periosteal sarcoma (Figs. 202 and 203), and here it is extremely malignant. Amputation at the hip joint, or, if the growth is extremely small, below the trochanter, should be performed. Butlin collected from the literature fifty-four cases in which the end result was known. Out of this entire number there was one cure—a case in which the diagnosis was doubtful.

Wyeth, in a collection of 131 cases of hip-joint amputation done by his method, with a mortality of 10.6 per cent, determined the end results in 83, but he made no distinction between central and periosteal sarcoma, and many of his cures are probably in the giant-cell variety. Fourteen patients, 16 per

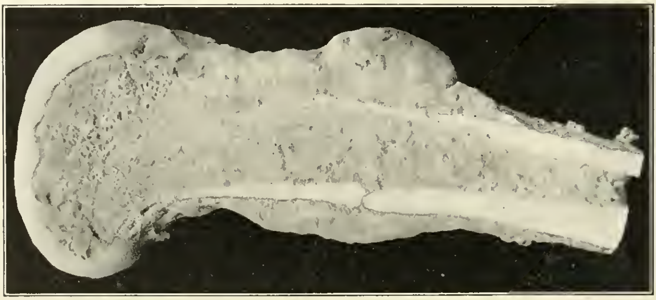


Fig. 202.—Periosteal and Medullary Spindle-cell Sarcoma of the Lower End of the Femur. (Warren Museum, Harvard Medical School.)

cent of the total number of cases, were alive at the end of three years, and in addition there were 9 others who were alive after the lapse of two years.

In central sarcoma of the femur (Fig. 204) the results are better. High amputation is the operation usually performed; disarticulation, except in tumors of the head of the bone or in large infiltrating growths, being unnecessary. In the pure giant-cell variety curetting may be done first and amputation later, if necessary. Resection of the bone almost invariably gives a poor functional result. Butlin has collected 46 cases of central sarcoma. His high mortality is due to the fact that many of the operations were done in pre-antiseptic days.

Butlin's Statistics.

Died at operation	11
Lost sight of	18
Dead, or alive with recurrence or metastases	2
Died, unknown cause	7
Well nine months	1
Well one to two years	2
Well over three years	5

In other words, 5 cases out of the 15 which survived the operation, may be called cured, while the result is yet to be determined in 3.

Tibia.—Next to the lower end of the femur the head of the tibia is the most common seat of sarcoma (Fig. 205). Amputation through the femur, in the periosteal type, is the operation of choice, although in some cases of the spindle-cell variety, which have a structure closely resembling that of the fibromata, enucleation may be justifiable. In Butlin's collection, consisting of 21 cases which survived the operation and in which the final result was known, 16 died

FIG. 203.—Medullary Giant-cell Sarcoma of the Lower End of the Femur. (Original.)

of metastases or of a recurrence of the growth, and, of the 5 surviving, but 1 was well for a period of over three years.

In the central giant-cell form (Fig. 204) curetting is to be recommended, as amputation can be done later, if necessitated by a recurrence of the growth. Resection, if the tumor is small, will give the same result as in other diseases in which resection of the knee joint is practised, but it is generally necessary to remove more bone than is required under other circumstances, and the leg is consequently much shortened. Out of 20 cases of central sarcoma of the head of the tibia, in which various operations were performed and the final re-

sult was ascertained, nearly 50 per cent were living at the termination of fully three years, while 9 others had remained well for periods ranging from one to two years, and only 2 were known to have died of a recurrence of the growth or of metastases (Butlin).

Fibula.—The fibula is comparatively rarely attacked, and the usual rules

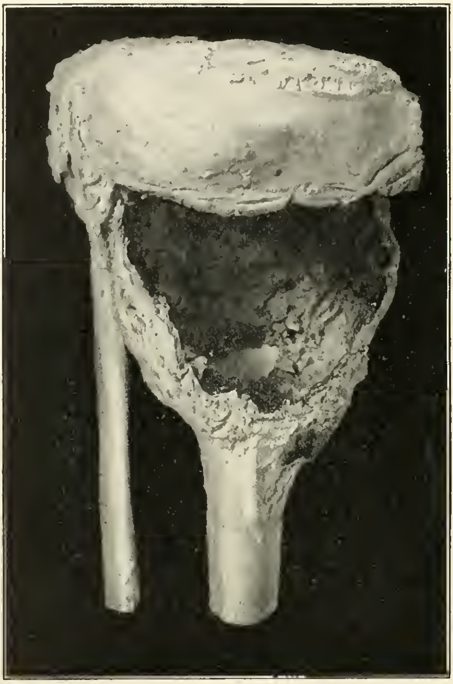


Fig. 204.—Central Giant-cell Sarcoma of the Head of the Tibia (Spina Ventosa). (Warren Museum, Harvard Medical School.)

regarding treatment of the various types of growth apply with equal force to these cases. Resection should be given the preference over curetting for central tumors of any appreciable size, as it causes but little disability (Fig. 206).

MULTIPLE MYELOMA.

Synonyms: osteomalacia, myelogenous pseudo-leukæmia, sarcomatous osteitis, lymphadenoma, hyperplásia of the marrow, etc.

Definition.—A primary, multiple neoplasm of the bone marrow affecting chiefly the sternum, ribs, vertebræ, and skull, and, more rarely, the long bones of the skeleton. The growth replaces to a greater or less extent the bony tissue and may infiltrate the soft parts in the immediate neighborhood, but it differs from other malignant growths in that it never forms metastases in the soft parts.

FIG. 205.—Osteoid Sarcoma of the Head of the Tibia. (Massachusetts General Hospital.)

The disease was recognized as an entity in 1873 by von Rustizky, who gave it the name of multiple myeloma, but at the same time considered it a hypertrophy of the marrow. It is commonly known by this name in literature, but Wright, in 1898, demonstrated that in his case the tumor was composed of but one constituent of the bone marrow, viz., plasma cells, and he suggested the name of *plasmoma.* This term, however, has not as yet been universally adopted. Previous to von Rustizky's contribution, two cases had been described under the name of *osteomalacia*—one by Bence-Jones, in 1848, who called attention to the presence of albumoses in the urine, and a second by Weber, in 1867. In all, up to the present date, about 40 cases have been reported, many having been described during the past year. Some observers include under this designation a larger number of cases than a rigid scrutiny would seem to permit. Their pathological descriptions are oftentimes brief and unsatisfactory. (See Fig. 198.)

Etiology.—The etiology of multiple myeloma is as obscure as that of other hyperplastic conditions in the bone marrow, yet toxic agents appear to play a certain rôle. Men, usually of the working classes, are more commonly affected than women, the disease appearing in most instances between the ages of 40 and 50. The oldest case reported was that of a man 70 years old, the youngest a woman of 36. Syphilis has no important bearing on the disease, and, when it occurs in women, it has no relation to pregnancy or the puerperium. In 2 of the reported cases there was some question of heredity, one having had a brother

die of a similar disease, while the other lost a daughter of pernicious anæmia. As to trauma, out of 24 cases a history of some kind of injury was given in only 4, and in 2 of these the injury was inflicted many years previous to the appearance of the symptoms (Hoffmann). The possibility of its infectious origin has also been considered, and in support of this theory are the changes in the bone marrow known to take place in certain infectious diseases and after poisoning with arsenic. Furthermore, as the tumors are formed of plasma cells, they resemble greatly many of the so-called infectious granulomata.

Fig. 206.—Periosteal Large Round-cell Sarcoma of the Upper Part of the Fibula, showing new bone formation. From a girl of sixteen. (Warren Museum, Harvard Medical School.)

Pathological Anatomy.—The primary changes found post mortem have in all cases been limited to the bones, the other portions of the body being normal except for the changes that one would expect to find in any case of secondary anæmia of a high grade and those due to mechanical injury such as is wont to be caused by pressure and deformity of diseased bones. There have been no metastases, and the soft parts are involved only by a direct extension of the growth. The disease is most commonly seen in the form of multiple foci, first involving the bones that surround the thoracic cavity—the sternum, ribs, and vertebral column; later, the clavicle, skull, and long bones are attacked. In Wright's case, the sternum, ribs, vertebræ, and skull only were involved, while in that of Jellinek nearly every long bone in the body showed foci of the disease.

On section of the diseased bones, the marrow is replaced to a greater or less extent by a soft mushy growth varying from a whitish-gray color to a dark red (Plate XXIII, Fig. 1). In some places the growths are quite sharply defined from the normal bone marrow, in others they merge gradually into it, while in still others the marrow is entirely replaced by the new-growth. In bones like the ribs such a replacement of the marrow by the tumor tissue causes the cavity to become distended until it is separated from the surrounding tissues by

a mere shell of cortical bone, through which in places the new-growth may extend into the soft parts, forming palpable tumors. Owing to this extreme thinning of the cortical bone, multiple fractures of the ribs and long bones are common. In advanced cases the ribs may be entirely destroyed and their continuity lost in masses of tumor tissue. In the other bones the changes are similar in appearance to those in the ribs. In the vertebræ the softening of the bodies causes deformity, with pressure on the cord and the degenerative changes resulting therefrom. In the skull the cortical bone is destroyed early, leaving irregular, circular defects with rough edges, filled with the tumor growth.

There is considerable variation in the description of the microscopic findings, many of the cases having been poorly reported. Microscopically, the tumors show a delicate stroma in which lie, loosely, round cells, singly, or closely packed together; but when they are under pressure the cells assume a polyhedral shape. They vary somewhat in size in different cases and even in the same case. Thus, for example, a comparison of the slides of Wright's case with those from Thomas' reveals the fact that the cells in the latter are distinctly larger, although they evidently belong to the same type of tumor. The nucleus is of large size, of a somewhat irregular shape, and usually eccentrically placed. It has a distinct nuclear membrane and presents a well-marked central nucleolus, which, in sections stained with alkaline methylene blue and eosin, manifests a distinctly pinkish color. Around the borders of the nucleus are many dense masses of chromatin which are in close relation to the membrane, the central portion of the nucleus being clear. The protoplasm has a finely granular appearance, but these granules do not stain as do those of the neutrophilic myelocyte. Some of the cells are large and multinuclear and the protoplasm often shows vacuoles, the products of degeneration (Fig. 198). In most cases no mitotic figures have been observed, but appearances pointing to amitotic division have been seen in many of the tumors. The derivation of these cells is still doubtful. Wright was the first to point out their similarity to plasma cells; and, while some observers agree with Wright, others believe that the cells are derived from the myelocytes. McCallum calls attention to their similarity to the young myelocyte, which does not show the neutrophilic granules, and he traces the gradual transition from normal marrow to tumor structure. The tumors are vascular and show many areas of hemorrhage.

Urine.—The interest in the urine centres in the presence of an albuminous body which was first described by Bence-Jones in 1848. This body was thought to be albumose, but recently there has been considerable discussion as to its exact nature. It is not absolutely constant, but is probably present at some time during the course of the disease. In nearly all the cases it appears as an early, a late, or a transient symptom. Fitz has mentioned its presence in a case of myxœdema, and Askanazy observed it in a case of lymphatic leukæmia; but, as a rule, although traces are found in many diseases, it is never present

in as large quantities as in multiple myeloma. Moffatt has collected forty cases, all of which, with the exception of the two noted above, are probably cases of myeloma. The amount of this albuminous body varies up to six per cent, but is usually less than one per cent, and may be regarded as an almost pathognomonic sign.

Blood.—The blood shows the changes of an anæmia of high grade. There is no leucocytosis, and the differential count of the white cells is normal.

Symptoms.—The clinical picture of the disease varies greatly, according as to whether one or another symptom predominates. Pain referred to the bones, more particularly those of the chest, is usually the first symptom, but cases have been reported in which pain was not prominent, the chief symptoms of the disease being those of pernicious anæmia. In general, pain in the bones, deformity, spontaneous fracture, progressive anæmia, and Bence-Jones albumosuria are the cardinal symptoms.

Hamburger has divided the disease, for convenience, into four main types, according as to whether one or another symptom predominates. In the first class are those cases in which attention is first called to pain in the bone affected, usually one of the ribs, followed by deformity of the chest and spine, with the resulting kyphosis and symptoms due to pressure on the cord—paralysis, paræsthesias, incontinence, etc. The pain is usually dull, but is sometimes lancinating, and is often interspersed with periods of comparative comfort.

In the second class the symptoms are similar to the foregoing, but at the same time there are present multiple tumors of the ribs, sternum, spine, often of the skull, and sometimes of the extremities—tumors which are usually soft and which are often associated with the symptoms and deformities that result from multiple fractures.

In the third class belong those cases in which the disease runs a rapid course and of which the chief symptoms are those of a pernicious anæmia—cachexia, fever, sweats, hæmoptysis, subcutaneous hemorrhages, and effusion into the serous cavities, the bone symptoms being in abeyance. Enlarged spleen and lymph nodes, nausea, vomiting, and neuralgia may also be present.

In the fourth class are included those cases in which there are prominent nervous symptoms which are not due to pressure, viz., anæsthesias, paræsthesias, and locomotive disturbances, and paralyses such as the hypoglossal paralysis spoken of by Senator.

Diagnosis.—So far as the diagnosis is concerned the chief points are: The presence of multiple bone tumors, either palpable or demonstrable with the x-ray, some pain and deformity, the presence of albumose in the urine, and the negative results of an examination of the blood. In making a differential diagnosis it is necessary to bear in mind osteomalacia, osteoporosis, osteitis deformans, osteomyelitis, multiple sarcoma, chloroma, and certain blood and nervous diseases, but, if the examination is made with due care, all these may be easily excluded.

Prognosis.—The prognosis is invariably bad, the disease running its course, apparently uninfluenced by treatment, in from two months to seven years.

Treatment.—The treatment is unsatisfactory, and no surgical measures, except for the relief of symptoms, are of any avail. In Thomas' case and one other unpublished case where paralysis was caused by a kyphosis due to the disease invading the vertebræ, marked relief was afforded by a laminectomy. Exposure to the Roentgen rays has been suggested because of the alleged beneficial results obtained by their use in some other forms of sarcoma, but their employment will not probably influence materially the course of the disease. Coley's serum was employed in Thomas' case with some apparent success in temporarily relieving symptoms, although the patient eventually succumbed to the disease. The dose was four minims every three days, and this was increased later to eight minims.

The disease should be treated on general principles and the symptoms met as they arise. Ice was useful in one case in relieving pain, but usually it is necessary to resort to morphine.

ENDOTHELIOMA.

Endothelioma of bone is a rare tumor, and originates, as elsewhere, from the endothelial cells of the blood-vessels or from those of the lining of the perivascular lymph spaces. Hildebrand, in 1891, found 8 cases in the literature, and recently Howard and Crile have collected 23, but it is extremely probable that certain of the reported cases represent metastatic deposits of a hypernephroma, the original focus having been overlooked. Albrecht, in a collection of 28 cases of hypernephroma, found metastases in the bones eight times, all of them closely resembling primary endothelioma. On the other hand, probably some cases of endothelioma of bone have been reported as primary bone cancer.

As to the etiology little is known. Trauma has been mentioned in a few cases, but probably it is of minor significance. The tumors occur at any time of life, but are distinctly more common after forty than before that age, in this respect resembling carcinoma. The sexes are about equally affected, the tumor being slightly more common in the male. Endotheliomata occur most commonly in the long bones, but they are also seen in the flat bones, notably on the cranium. An unusual feature of these tumors is their multiplicity. Thus, in 13 cases in which the bones were carefully examined, 9 showed more than one bone affected and 4 showed multiple tumors of a single bone. Whether these tumors start simultaneously, or whether one is the primary focus and the others are secondary to it, are questions which still remain unsettled.

Pathology.—Endotheliomata usually originate in the medulla at the epiphyseal end of a long bone, as is true of sarcoma, this being the portion of the

bone richest in blood-vessels. They may develop, however, beneath the periosteum or in the shaft. The tumors themselves are soft and surrounded by a definite capsule composed of fibrous tissue or bone. On section, they are reddish or gray in color and present numerous cavities filled with blood, but they never contain bone. Histologically, there is some discussion as to the exact point of origin of these tumors. As the perithelial cells of Waldeyer are not seen around the small vessels in the bone, Howard and Crile conclude that two varieties can be distinguished: (1) those arising from the lymph vessels, and (2) those arising from the endothelium of the blood-vessels or perivascular lymph spaces. Microscopically, the tumors are quite characteristic, and two types can be distinguished, depending somewhat on the arrangement of the vessels. Thus, if the vessels preserve their normal relations the cells are seen in long columns—the tubular type; whereas, if the normal arrangement of the vessels is lost, the alveolar disposition of the cells is seen. At the same time it is a fact that both modes of arrangement are usually demonstrable in the same tumor. In the alveolar type the cells are seen in radiating concentric layers about a central lumen, which represents the vessel around which they originated. In some tumors the cells are separated from the lumen (which may or may not contain blood) by a thin layer of connective tissue, which would be the case if they originated from the perivascular lymph spaces, while in others they form the walls of the vessels. In the early stages the alveoli are separated by considerable fibrous tissue, but, as the tumor grows, this fibrous tissue disappears and the cells around one vessel appear in direct contact with those around an adjoining vessel. Degenerative changes are common, and at times hyaline bodies are seen among the cells or as drops in the protoplasm (cylindroma). In the endotheliomata which are said to arise from the lymph vessels, the cells are similar to those of the foregoing variety, but they have no definite arrangement and are not visibly connected with the vessels. They closely resemble carcinomata.

Symptoms.—The symptoms are similar to those of sarcoma; there is a tumor which originates as a fusiform swelling near the epiphysis in the long bones, or as a lobulated swelling in the flat bones, and is accompanied by some pain and progressive cachexia. The consistency varies from soft to hard, according to whether there is a fibrous or a bony capsule. If it be soft, there may be an expansile pulsation and the tumor may be reduced perceptibly in size by pressure, while on auscultation in these cases a bruit synchronous with the heart sounds may be heard as in an aneurism. In some cases also the growth will diminish in size when pressure is made on the main artery of the limb. The bruit is caused by the passage of blood through the large sinuses.

Diagnosis.—Clinically, it is not possible to make a diagnosis between sarcoma and endothelioma. The late age at which the tumor occurs and also the presence of multiple growths may be suggestive. Microscopically, the arrange-

ment of the cells in alveoli of large size and of uniform type, so placed that they constitute the walls of the vessels, the presence of hyaline degeneration, and the absence of bone, are features quite distinctive of endothelioma. In angiosarcoma the cells are not of uniform type, and bone is usually present. The possibility of the tumor being a metastatic adrenal growth should be borne in mind.

Treatment.—The treatment is the same as for sarcoma. In the long bones, in view of the malignancy of the growth and its tendency to extend up the marrow cavity, amputation is to be advised.

Prognosis.—The prognosis is bad, as about two-thirds of the tumors are multiple or have already formed metastases at the time when they are first seen. When a single bone is affected and it is possible to amputate, and if also the disease is seen in its early stages, there is a chance of effecting a cure.

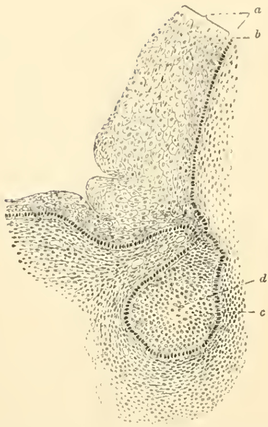
ODONTOMA.

Odontoma is the name that has been applied to those tumors of the jaws which originate from some part of a malformed tooth germ. These tumors vary greatly in appearance and type, and, at first glance, appear to have nothing in common, but a careful study shows that they all develop from the teeth, the form of tumor varying according to the portion of the tooth follicle from which they arise. As the tooth is formed partly from the ectoderm and partly from the mesoderm, the reason for this variation is at once obvious, some of the tumors forming wholly from the mesenchymal tissues (fibroma, etc.), others from the epithelium (adamantine epithelioma, dentigerous cysts, etc.), while still others originate from both layers, one or the other usually predominating. The names often applied are based on the appearance of the tumors and give no suggestion of their origin. Although, therefore, some are clearly epithelial while others are connective-tissue tumors, it seems best, when the etiology is considered, to follow the classification suggested by Bland-Sutton * and group all of these growths under the common heading of odontoma or "tooth tumors."

For a proper understanding of these tumors it is necessary to have a clear idea of the formation of the teeth as it normally occurs. At about the sixth week of embryonic life a thickened band of ectodermal tissue is seen under the primitive oral epithelium, in the position of the gums, extending backward in an unbroken line toward the mandibular articulation. Over this a groove—known as the dental groove—is soon seen growing into the mesodermic tissue.

This dental groove constitutes a common epithelial invagination, the further development of the individual teeth being marked by local thickenings—the first indications of the enamel organs of the temporary teeth, organs which are

* "Tumors, Innocent and Malign."



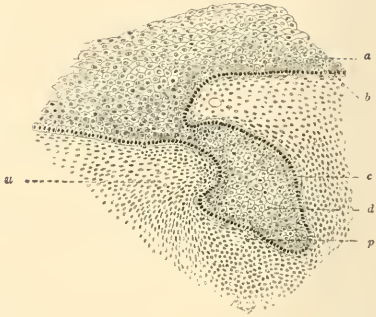
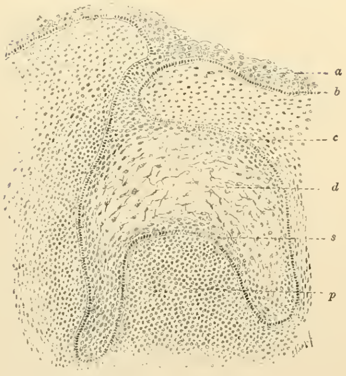


FIG. 208.—Section of the Papilla of the Tooth in its Earliest Stage. (Magnified 110 diameters.)

FIG. 207. Section of the Rudimentary Enamel Organ, only separated from the buccal epithelium by the dental ridge. (Magnified 110 diameters.)



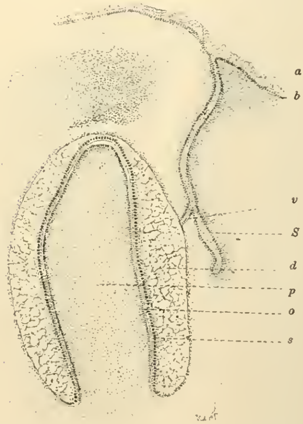


FIG. 209.—Section through the Papilla of the Tooth at a More Advanced Stage of Development. The enamel pulp is becoming differentiated. (Magnified 110 diameters.)

FIG. 210.—A Still Later Stage in the Development of the Tooth. The illustration shows the outgrowth from the rudimentary enamel germ, which later forms the enamel organ of the permanent tooth. There is some differentiation of the odontoblasts. (Magnified 40 diameters.)

FIGS. 207 to 210.—Sections of a Milk-Tooth of a Sheep Embryo, showing four different stages of development. The specimen was taken from the lower jaw. (Böhm and Davidoff.)

a, Epithelium of the cavity of the mouth; *b*, basal layer of the same; *c*, superficial cells of the enamel organ; *d*, enamel pulp; *p*, papilla of the tooth; *s*, adamantoblasts; *o*, odontoblasts; *S*, enamel organ of the permanent tooth; *v*, portion of the enamel germ of the milk tooth; *u*, adjacent connective tissue.

of ectodermal origin (Fig. 207). The intervening portion of the dental ridge then disappears, and the enamel organs are seen at this period of development as epithelial tongues projecting into the mesodermic tissue. As the formation of the teeth progresses, the lower portion of the enamel organ becomes flattened and presents a cup-shaped depression, while the connection with the epithelium covering the gums becomes at the same time less marked and finally disappears (Fig. 208). Coincidently with these changes the mesodermic tissue in the vicinity shows condensation and forms the dental papilla which grows upward into the cup-shaped depression in the lower portion of the enamel organ. This process continues until the enamel organ covers about two-thirds of the dental papilla. The inner portion of the enamel organ soon undergoes a myxomatous degenerative change, the growth of the enamel occurring only from the inner layer of columnar epithelial cells, and the inner and outer layers finally coalesce and form the cap of the tooth (Fig. 209). The description of the formation of the enamel, as given above, has reference to the temporary teeth, the enamel organ of the permanent teeth being formed from a bud that grows out of the atrophied epithelial canal which formerly connected the primary enamel organ with the oral epithelium. As these changes are taking place the mesodermic tissue in the vicinity becomes denser and eventually forms a fibrous sac enclosing the tooth and known as the tooth sac (Fig. 210).

It is easy to understand how tumors that originate from the different portions of the tooth follicle present widely different characteristics, and also how tumors that arise from the same portions of the follicle vary according to the stage of development of that portion at the time of their origin. Thus, a tumor originating from any portion of the dental papilla in its early stage of development would be somewhat conglomerate, but if it arose later, after the papilla had become differentiated into the roots and cementum, the composition of the tumor would depend on the portion of the papilla from which it started. In the same manner tumors may form late from the enamel organ, in which case they show characteristic columnar epithelium; or they may arise from remnants of the epithelium which connected the enamel organ with the oral mucous membrane (paradental epithelial débris), in which case they may contain stratified squamous epithelium derived originally from the gum and not so highly differentiated as that of the enamel organ in the later stages. The mixed forms, in which several of the tissues forming the teeth are present at different stages of development, display a very complicated histological picture.

In man the epithelial type of odontoma is the more common, and the tumors of this type are seen as cysts lined with columnar or cuboidal epithelium or containing gland-like areas in their wall. The odontomas of the fibrous type, although they do occur in man, are more apt to be seen in animals. Many classifications of these tumors have been given.

Broca distinguishes four varieties: (1) Embryoplastic odontomas, (2) odon-

toplastic odontomas, (3) coronary odontomas, (4) radicular odontomas. Other authorities distinguish between fibrous and epithelial tumors of the jaw originating from the teeth. Still others speak of cystic and solid tumors of the jaw, assuming, erroneously, that all the cysts have a common origin.

The classification adopted by Bland-Sutton is based on the embryological origin of these tumors and is by far the most comprehensive, although at first glance it is rather complicated. His classification is as follows:

Epithelial odontoma (from the enamel organ).	
Follicular "	(from the follicle).
Fibrous "	
Cementous "	
Compound follicular	
Radicular odontoma (from the root).	
Composite "	(from the whole germ).

Of these, the epithelial, follicular, and composite forms are commonly cystic.

Etiology.—The etiology of odontomas, apart from the fact that they arise from the tooth germ, is obscure. Failure of the tooth to erupt is not alone sufficient cause, inasmuch as perfectly formed, unerupted teeth occur with comparative frequency and as a rule rise give to no symptoms. Non-eruption of certain teeth has been mentioned by certain writers as being hereditary. Rachitis in certain cases probably plays some rôle, but it certainly is not present in all. Females are slightly more commonly affected than males, and the lower jaw—if all the different forms of tumors be taken into consideration—is somewhat more often involved than the upper. The tumors appear at about the time when the tooth from which they originate should erupt, and are, therefore, usually seen in children and young adults, being commonest between the ages of twelve and twenty-five. Cases have been reported in children of five years and also in old people; in the latter, however, they are usually of long duration. They are seen in connection with the permanent teeth, but a few rare cases have been reported in connection with the temporary set. The commonest teeth affected are the molars, and next to these the canines, while the other teeth are affected only rarely, but with about equal frequency. In all forms, with the possible exception of the radicular and those in which the growth starts from epithelial débris, the tooth affected is missing from the jaw. In the radicular form, however, the crown of the tooth may be perfectly formed.

Epithelial Odontoma.—(Synonyms: adamantine epithelioma, adamantinoma, cystic carcinoma, adeno-sarcoma of jaw, multilocular dentigerous cyst, cystadenoma of the jaw.) These tumors are usually seen somewhat later in life than the other forms of odontoma. Pincus,* in a collection of twenty-five cases of cystadenoma of the jaw, placing the age between twenty and forty. In some cases

* Arch. f. klin. Chir., 1904, lxxii., 995.

they start from the enamel organ proper, but in many cases the patient presents a full set of teeth, and in these cases the tumors probably originate from epithelial débris. The lower jaw is much more often affected than the upper, the tumor being situated in the centre of the bone and slowly distending it; and, although the growth may be situated near the alveolar border, it is more often located in the body of the jaw at some distance from the teeth. Females are somewhat more frequently affected than males: in the collection of cases made by Pincus the proportion was 16 females to 9 males; in that of Steensland* it

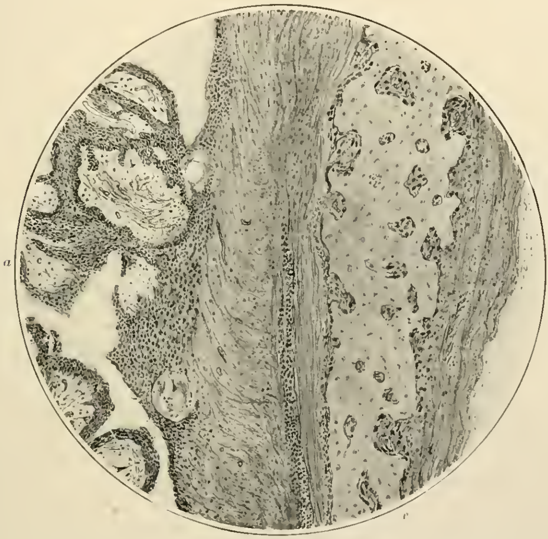


FIG. 211.—Section of the Wall of a Cystic Epithelial Odontoma (Adamantine Epithelioma). *a*, Portion of the jaw; *b*, fibrous tissue; *c*, adamantine epithelium. (Original.)

was 10 females to 8 males. On section, the tumor appears in the form of a collection of irregularly shaped multilocular cysts, the whole being surrounded by a thin shell of bone, from the sides of which fine bony trabeculæ often penetrate between the individual cysts. As a rule, however, the trabeculæ are fibrous. The cysts vary greatly in number and size, rarely being more than 2 cm. in diameter. In some cases, however, the tumors appear nearly solid, the cystic dilatation being demonstrable only with the microscope. They are filled with either a colloid-like material or, more commonly, with a brownish or reddish fluid containing cholesterin crystals. Microscopically, the bony shell surrounding the tumor is irregular and presents many osteoblasts and osteoclasts. The

* Jour. Exper. Med., vi 377, 1904.

cysts are separated by a connective-tissue stroma in which appear branching clefts, irregular in shape and lined with columnar epithelium derived from the enamel organ and of characteristic appearance. Some of the epithelium is cuboidal in form, and at times two layers can be distinguished. Under the epithelium is a loose tissue composed of branching stellate cells which represent the enamel pulp. The tumors of this class resemble very closely at first glance those which belong under the heading of Adeno-carcinoma. (Fig. 211.)

Follicular Odontoma (*Dentigerous Cysts*).—These tumors probably constitute the most common form of odontoma. They arise from the tooth follicle and they represent the distended sac. They are benign and of slow growth, but occasionally, especially if they originate in the upper jaw where they encroach upon the antrum, they attain enormous dimensions. The common form is seen as a flattened swelling of the jaw below the alveolus on the outer surface, rarely being present in the centre of the jaw or on its inner aspect. Pathologically, they consist of a unilocular cyst of irregular shape in the substance of the bone, with fibrous walls of varying thickness. These are lined with granulation tissue and are filled with dark-colored blood and detritus, and usually contain some portion of the tooth from which they arise, this tooth being missing in the jaw.

There is a type of cyst, of comparatively rare occurrence, which clinically cannot be distinguished from these dentigerous cysts. They are lined with epithelium, usually stratified, and contain thick yellowish material, rich in cholesterin crystals. They are seen where there is the full complement of teeth and arise from paradental rests. They are probably what some of the authors term dermoid cysts of the jaw.

Fibrous Odontoma (*Central Fibroma of Jaw*).—These tumors also develop from the tooth follicle, and all grades may be seen from the thin-walled cyst to the solid fibroma. The fibromata are firm, of a reddish color, and on section usually show in their centre some portions of the tooth from whose sac they arise. Microscopically, they are composed of dense, fibrous tissue, having a somewhat lamellated arrangement and in places calcified. These tumors have been, when cellular, often mistaken for sarcoma. Almost all of the fibromata of the jaw probably belong to the odontomata, and Blauel, in a collection of 40 cases, among which were 3 of his own, comes to this conclusion. Of this total of 40 cases only 11 were of central origin.

The *cementoma* of Bland-Sutton is a completely calcified fibrous odontoma and is rare in man.

Compound Follicular Odontoma.—The tumors of this class also arise from the follicle and are in reality only a variation of the fibrous form. The name is applied to those tumors which are composed mainly of fibrous tissue, but which are somewhat cystic, and which show in the cyst walls numerous calcified areas. Owing to a faulty development of the other portions of the tooth

germ, they often contain irregular small masses of cementum, enamel, and dentine, simulating small misformed teeth. These bodies may be present in large numbers.

Radicular odontomas are formed from the root of the tooth, as the name implies, and are of rare occurrence in man.

Composite Odontoma.—This name has been applied by Bland-Sutton to those irregular, sometimes partly cystic tumors which are formed of a conglomerate mass of dentine, cementum, and enamel, and at times reach an enormous size. They are similar to the compound follicular form.

Cysts are also seen in connection with the roots of the permanent teeth; they vary in size up to 2 cm. in diameter, but are usually much smaller. These cysts are lined with granulation tissue, and, as they are often seen with a diseased tooth, they are commonly spoken of as being of inflammatory origin. According to other authorities they represent remains of the tooth sac.

Symptoms.—Apart from those caused by the presence of a tumor there are few symptoms connected with the odontomata. They appear as painless swellings at about the time when the tooth from which they arise should erupt, and they slowly expand the jaw, growing, as a rule, outward. They are of slow growth, not attaining a large size for many years. If in the upper jaw they invade the antrum, and if they remain untreated they may eventually attain an enormous size, causing great deformity of the cheeks, nares, and jaws, and even encroaching on the orbit. Symptoms due to pressure on the neighboring nerves and organs, and trouble with breathing and deglutition may be present. Pain is not common. Ulceration may occur and the cervical lymph nodes may be enlarged. If the growth is cystic the crackling sensation obtained in all soft tumors contained in a thin-walled bony cavity may be elicited. If the tumor originated from a tooth, as is usually the case, and not from epithelial débris, examination of the teeth will show one to be lacking.

Diagnosis.—A tumor that arises in a young adult in the central portion of the jaw, that has a smooth outline, and that causes the jaw to bulge outward, is, when associated with an unerupted tooth, strongly suggestive of an odontoma. Other tumors which arise in this region and are liable to be confounded with it are carcinomata, sarcomata, exostoses, and chondromas. Exostoses are usually superficial, as are also chondromas, and at the same time they are harder, nodular, and more circumscribed, a distinction, however, which it is difficult to make in some cases. The *x*-ray is of value in certain cases in differentiating between osteomata and cystic odontomata. Carcinoma is a disease of later life, is much more common in the upper than the lower jaw, and is associated, when originating in the oral cavity, with early ulceration. Sarcoma, particularly when the odontoma is solid and is located in the upper jaw or at the angle of the lower jaw, cannot in many cases be ruled out, especially if there is a full complement of teeth. In any case, if the presence of an odontoma is suspected and if a

major operation is contemplated, tapping—which in the case of a cyst will immediately clear up the diagnosis—should first be resorted to. Great care should also be taken in making a pathological diagnosis from small bits of tissue removed from the outer portions of the growth, as the fibrous forms are often very cellular, resembling spindle-cell sarcomata, and as all forms may contain giant cells.

Treatment.—It should be borne in mind that all the forms of these growths are essentially benign, and that a radical operation is rarely justifiable. The treatment naturally varies with the size and position of the tumor, and each case must be considered separately and treated according to its individual requirements. In odontomas of the epithelial variety, excision should be done, care being taken to remove all the growth, but it is not often necessary to remove half of the jaw.

In the common follicular type, or dentigerous cyst, it is only necessary to remove the anterior wall and curette the interior. In the other rarer forms, excision of the growth should be practised. The fibromata are at times easily shelled out, while in other cases it is necessary to remove some of the bone.

Prognosis.—In the epithelial variety, recurrences have been reported after complete excision, but these recurrent growths are, as a rule, local, and can be easily removed, although there is a possibility of the tumor assuming a malignant character. In the other forms, particularly the cystic, the prognosis, with operation, is favorable, and if the growth is of small size the resulting deformity will be slight or there may be none whatever.

EPITHELIAL TUMORS.

Primary Epithelial Tumors.

Primary epithelial tumors of bone, with the exception of those which develop from cut-off and misplaced embryonic remains, cannot occur. Other epithelial tumors of bone either represent metastases or are due to the direct extension of a pathological process. The older literature abounds in reports of cases of primary cancer of the bone, but these, in the light of our present knowledge, are either metastatic growths (the original focus having been overlooked), hypernephromata, endotheliomata, or angio-sarcomata.

There are certain epithelial tumors of bone of developmental origin, and of these the epithelial odontoma of the jaw, which arises from the paradental epithelial débris, is the best example. Another example is furnished by the teratomatous tumors of the sacrum which contain epithelial structures and which are similar to that observed in the case reported by Lubarsch.

Epidermoid cysts of the bone are occasionally seen, and of these the cysts of the jaw that develop from the paradental epithelial débris are the most com-

mon. The other types are seen almost invariably in the skull and represent embryonic defects. They are commonly situated at the fontanelles, in the median line or in the temporal region, but they are also seen around the orbit; they closely resemble encephalocele. When opened, they are seen to be lined with stratified epithelium and to contain epithelial débris, cholesterin, and occasionally hair.

Another variety is at times seen in the mastoid process (cholesteatoma), but most, if not all, of these tumors are probably due to retained secretions and are not true new-growths.

Secondary Epithelial Tumors.

Epithelial tumors may involve the bone either as the result of a metastatic process or by a direct extension of the disease. Thus, epithelioma is not rarely seen in old, granulating, osteomyelitic cavities of long duration, and in these cases the tumor extends often for a considerable distance into the medullary cavity and is usually accompanied by marked hyperostosis. A similar condition may be seen at the base of chronic ulcers situated over bone, and in old suppurating bone cavities with sinuses. The chief characteristics of these tumors are their slow growth and the marked degree of the accompanying hyperostosis. Of the cancers that involve the bone by direct extension, those of the jaw are the commonest.

Metastatic epithelial tumors of the bone are not uncommon; and although all forms of carcinoma may occasionally form bony metastases, secondary involvement of bone occurs, as a general rule, in only a few cases. In 20 cases of metastatic cancer of the bone the site of the original tumor was as follows*:

Breast	5	Uterus	2
Stomach	4	Gall bladder	1
Rectum	3	Œsophagus	1
Lung	3	General carcinoma	1

The same observer also reports 17 cases of metastatic bone cancer, the primary focus being in the prostate. Adeno-carcinoma of the thyroid is also prone to form metastases in bone.

As will be observed in the above table, the commonest cancers affecting the bones are those of the breast, particularly the slowly growing scirrhous varieties. These form metastases early,—in the sternum or vertebræ, occasionally in the humerus or skull,—but, as a rule, the bone metastases are confined to the upper portion of the body. They are more apt to be circumscribed tumors than are the metastases from prostatic cancer.

In the male, cancer of the bone is most commonly secondary to carcinoma

*Fischer-Defoy: Centralbl. f. Chir., 1905, 1076.

of the prostate, and the metastases are limited to the pelvis, the lumbar vertebræ, and the bones of the lower extremity. In this form of cancer the abdominal lymph nodes and viscera are rarely involved, the metastases being present only in the bone and the parent tumor often being extremely small. von Recklinghausen in 1891 was the first to call attention to this condition and since then many cases have been reported, the last series by Fischer Defoy. One characteristic of these tumors is their preference for those bones which are under a constant strain (either a push or a pull), as is true of the femur and the vertebræ.

The cells in cancer of the bone are probably carried to it through the bloodvessels and not through the lymph channels, as is usual in cancerous metastases of the soft parts. They lodge in the bone, as there the capillaries are large, venous in character, and do not contain muscular tissue in their walls.

Cancer of the bone may be either single or multiple, localized or diffuse, and is of slow growth. The localized metastases occur as single tumors in the marrow, and there gradually destroy the bone, while at the same time a new formation of bone takes place around the growth. However, the metastatic bone cancer most commonly seen, particularly that which develops secondarily to cancer of the prostate, is of a diffuse character, the tumor infiltrating the bone slowly, destroying and replacing it. Around the cancer there occurs a marked new formation of bone, and bone destruction, osteoporosis, osteosclerosis, exostoses, etc., are seen in the same bone. This leads to bowing and marked deformity, and to this condition the names of cancerous osteomalacia, osteoplastic cancer, and cancerous ostitis have been applied. Microscopically, in these cases the cells, which closely resemble those of endothelioma or alveolar sarcoma, are seen infiltrating the bone.

Tumors Composed of Thyroid Tissue.—There are seen at times solitary or multiple bone tumors which are composed of typical adenomatous thyroid tissue, and yet which are not necessarily accompanied by goitre. These tumors are most commonly seen in the sternum, vertebræ, humerus, and skull. As regards their origin there is considerable difference of opinion. Bormann, Oderfeldt, Steinhaus, and others consider them as being examples of metastasis occurring in a benign tumor, that is, a simple adenoma of the thyroid; while von Recklinghausen, Huguenin,* and with them the majority of observers, consider them as metastases of a microscopic malignant thyroid tumor, which has been overlooked; and there is nothing in the reported cases to disprove this. The possibility of their being in some cases embryonic inclusions is to be thought of. von Eiselsberg, in 1893, reported 8 cases, the tumors being multiple in 3 instances.

These tumors are of slow growth, very vascular, and they may represent

* Deutsche Zeitsch. f. clin. Chir., 1904, lxxiii.

simple adenomatous thyroid tissue or be frankly malignant in character, and the diagnosis is possible only with a microscope.

The question as to the desirability—in order to prevent other metastases—of removing the thyroid gland, after the diagnosis has been made, has come up for consideration, but the consensus of opinion is rather against the adoption of such a course, the view being held that, if one metastasis has already formed, there are probably others, as was found in the case reported by Housell, and

FIG. 212.—Photomicrograph of a Metastatic Hypernephroma of Bone. Note the arrangement of the cells in columns and alveoli. (Original.)

that consequently it would be useless to perform thyroidectomy. On the other hand, it is known that in several reported cases removal of the metastasis has been followed by a permanent cure.

METASTATIC HYPERNEPHROMA.

Metastases in bone from hypernephroma—"Grawitz' tumor"—are of comparatively common occurrence and are often overlooked, many of the cases of so-called primary endothelioma of bone being in all probability instances of metastatic hypernephroma. Albrecht* has recently reported 28 cases of hypernephroma, in 8 of which he was able to demonstrate metastases in the bones. Metastases occur in these tumors in the same manner as they do in sarcoma, *i.e.*, through the blood-vessels, the secondary growths appearing sometimes in

* Deutsch. Gesell. für Chir., xxxiv., 620, 1905.

the shaft, at other times in the epiphyseal ends of the bones. Any bone in the body may be the seat of the growth, cases having been reported as occurring in the clavicle, femur, humerus, scapula, etc. Microscopically, the tumors are characteristic of hypernephroma; that is, they possess large cells disposed in an alveolar or a tubular arrangement, the alveoli being separated by a small amount of very vascular connective tissue (Fig. 212).

Clinically, hypernephroma is seen at the average age of 48 (Grawitz); that is, it develops somewhat later than does sarcoma. But the differential diagnosis between sarcoma and hypernephroma is impossible, although, if the growth is associated with a palpable tumor of the kidney, hypernephroma should be seriously considered. The prognosis is bad because the presence of metastases in bone indicates that there are probably metastases in the soft parts.

PARASITIC TUMORS OF THE BONES.

Echinococcus.—Echinococcus disease of the bones is occasionally seen, and differs considerably from the same disease as it affects the soft parts. It was recognized in the early part of the century, and many collections of cases have been made, notably by Reezey, Gangolph, and more recently by Taggett, who collected 76 cases from the literature. It is an extremely rare condition and probably constitutes about one per cent of all cases of hydatid disease; many authorities, however, place the percentage even lower. Poulton found but 1 case in 279 of hydatid disease.

Echinococcus disease may occur in any bone, but is somewhat more common in the humerus, femur, and tibia. In Gangolph's series the different bones were affected as stated in the following table:

Femur	6 times	Pelvis	11 times
Tibia and fibula	8 "	Skull	4 "
Humerus	11 "	Scapula	1 "
Phalanges	1 "	Sternum	1 "
Vertebræ	8 "	Ribs	1 "

The manner in which the infection takes place is not clearly understood. The parasites, when ingested, get into the portal circulation and commonly lodge in the liver, but if the embryo succeeds in passing through the liver capillaries it lodges in the lungs. As these embryos are about 20μ in diameter, it is impossible to understand how they can pass through the capillaries in the lungs which are only 7μ in diameter; and also why they should then lodge in the large capillaries of the bone. Trauma and extravasation are probably important factors in determining the seat of the cysts.

Pathology.—Echinococcus disease in bone differs greatly from the usual type seen in the soft parts. Parent cysts containing daughter cysts are not

found; from the very first there are multiple small cysts which slowly increase in size and multiply by buds that develop on the outside of the parent cyst. This type is somewhat similar to the rare form of multiple small cysts observed in the liver. Because of this radical difference many maintain that the parasite in echinococcus bone disease differs from that observed in the other forms of the disease; but Virchow's theory that the surroundings determine the type of the disease is generally accepted, and in advanced disseminated hydatid disease both forms are seen—the one in the bones, the other in the soft parts. Scolices and hooklets are occasionally, though rarely, found in the cysts. The latter are seen usually in the articular end of the long bones in large numbers and slowly increase in size, destroying the bone by pressure. They continue to grow and multiply until a large bulging tumor is formed, invading the shaft and often breaking through the cortex, with infiltration of the surrounding soft parts or the joint. Necrosis, followed by infection and sequestrum-formation, is common, the bone in the latter stages having a worm-eaten appearance. The individual cysts are round, with thin walls, and they vary in size up to 2 cm. in diameter. They are filled with clear fluid, which, as in echinococcus cysts in other parts of the body, is free from albumin, but contains a variety of salts.

Symptoms.—The disease runs a very slow course, and in the early stages symptoms are often absent. Pain, usually slight and referred to the joint, is present at some time, and so also is swelling of the affected bone, with impairment of function of the part and, later, serious involvement of the neighboring joint. Pathological fracture in the long bones is of common occurrence. Infection of the growth occurs in nearly every case, with the resulting symptoms of an acute osteomyelitis. Examination shows an irregular swelling which may be hard or may present fluctuating points where the cysts have broken through the cortex.

Diagnosis.—It is impossible to make a diagnosis from the history or from an examination, and usually the disease is not recognized until it is revealed at the time of the operation, when the presence of small, multiple, budding cysts arouses suspicion. Inflammatory changes often completely mask the original condition.

Treatment.—The treatment consists in the thorough removal of the disease. In the long bones the process has often advanced so far at the time of operation, and the patient is usually in such poor condition as the result of sepsis, that amputation is necessary. In the less advanced cases and in echinococcus disease of the flat bones, thorough curetting after excision, care being taken to remove the marrow for some distance beyond the apparent limits of the growth, should be practised. Subperiosteal resection may be done in certain cases.

Prognosis.—The prognosis varies with the parts involved and the stage of the disease at the time of the operation. After amputation of a limb the chances

of return are of course small, but recurrences are common after the more palliative operations. When the vertebræ, skull, or pelvic bones are involved, the prognosis is not so good as when the disease is located in other bony structures.

Cysticercus Disease.—Cysts of the cysticercus cellulosæ, representing the larval stage of the Tænia solium, or pork tapeworm, have been reported as occurring in bone structure, but such cases are extremely rare. The disease may affect any bone, and it manifests itself by the presence of the typical cysticercus cyst, usually having a distinct fibrous capsule and containing the embryo. Mosler and Peiper* refer to two cases: one, reported by Froriep, in which the first phalanx of the middle finger was involved; and the other, reported by Bastrom, in which the upper end of the tibia was the seat of the disease.

* Nothnagel: "Spec. Path. u. Therap.," 1894.

PART XIII.

DISEASES AND INJURIES OF JOINTS

CHRONIC NON-TUBERCULOUS AND NON-TRAUMATIC INFLAMMATIONS OF JOINTS.

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INTRODUCTORY REMARKS.

The preparation of an article on the chronic non-tuberculous and non-traumatic forms of arthritis, if it is to be comprehensive and at the same time practically useful to the student or practitioner, demands a careful classification of the subjects to be considered. Some of the conditions which will be treated are due to inflammation of various sorts, some to disease of a more insidious nature, some to traumatism, and some, finally, to injuries or diseases of the central nervous system. For the sake of convenience, therefore, I will discuss these topics in the order named, omitting from such consideration, in accordance with the limitations of the subject, the tuberculous joint lesions and those due to the introduction of septic material into the cavity of the joint, both of which subjects are discussed in another part of this volume. Recent progress in the study of arthritis has served to establish at least a working hypothesis, in accordance with which it is now possible to classify anew and more scientifically the so-called rheumatoid diseases. Contemporaneous observers in various parts of the world have been arriving at much the same conclusions in the matter, and, as a result, a better nomenclature is being evolved, and more is being accomplished in the way of treatment in this class of cases.

The term "rheumatic," as applied to these chronic arthritic conditions or processes, is no longer satisfying, and attempts are being made to do away with it altogether, or at least to restrict its application to a very narrow scope. The classification which is gaining widest acceptance in this country—a classification which was first propounded by Goldthwait and which has been independently advanced in a not very dissimilar form by Prîbram in Austria—divides the chronic joint lesions into those caused by infectious agents, those characterized by atrophic changes in the articulations, and those distinguished by hypertrophic changes. Around these terms may be classified with greater accuracy, as regards etiology, pathology, and clinical history, more of the chronic non-tuberculous arthritides than has been found possible about any other basis of classification that has heretofore been advanced. At the same time it must be admitted that there are borderland cases whose exact classifi-

cation is difficult, and that there are links in the chain of evidence in support of this differentiation which are not as yet very firmly forged; but it is a helpful, practical, working hypothesis.

I. INFECTIOUS POLYARTICULAR INFLAMMATIONS.

Etiology.

I shall consider first the group of polyarticular inflammations which in this classification are called infectious. This term is intended to imply that either bacteria themselves or their toxic products have had access to a joint or joints and have there given rise to lesions not necessarily characteristic of any specific organism, at least so far as any present knowledge can affirm, but are characteristic of some infectious process. Variations in the toxic products of any organism capable of producing lesions would, of course, produce variation in the intensity of local tissue reactions. Some organisms are also more virulent than others, independently of possible variability in their specific toxicity. Doubtless there are variations in the affinities of organisms belonging to various families of bacteria for different tissues, just as we know that individuals of the human family vary in their susceptibility to infection.

If we assume that the foregoing is true, it is easy to understand how great may be the variety of symptoms produced by an infection of the joints of an individual with bacteria or cocci, and if one studies these cases carefully, although he may not be able to say that this particular case or that particular individual has been infected by this or that organism, he will nevertheless be able, in a large majority of the instances, to say that a given symptom-complex could have been produced only by some infectious agent. To be able to do this is a great step in advance, for the knowledge which makes that possible is the key to the situation so far as treatment is concerned. These cases and those with which they are so often confused have been, and still are, regarded by many as hopeless so far as permanent benefit is concerned. They are consigned, if they happen to be poor, to almshouses and homes for incurables, and, if they belong to the well-to-do class, they are given attendants and made to feel resigned to an invalidism which might in very many cases be avoided.

The etiology, therefore, of this large group of cases can be in a measure established. There are certain members of it—the most conspicuous of which is acute articular rheumatism—which seem to be entities. No one, I think, is now disposed to dispute that acute articular rheumatism is an infection, although they may not be prepared to accept the bacteriological findings which have thus far been reported as representing the sole cause of the disease. Although in the acute stage the joint symptoms are the conspicuous features, yet this disease never leaves any permanent joint impairment. Its course conforms pretty closely to

that pursued by any of the acute infectious diseases in which joint signs are not present. Clinicians have thought that gonorrhœal arthritis was an entity which could be easily recognized, but it is probable that the features which have been regarded as sufficient to establish that diagnosis—viz., suddenness of onset, monarticular tendency in joint involvement, and a history of recent gonorrhœa—may not be sufficiently characteristic to warrant the calling of such a symptom-complex gonorrhœal arthritis. An arthritis following a pneumonia or a pleurisy or some other acute general infection (*e.g.*, typhoid or one of the exanthemata), or indeed any local infection, as for example a boil, a carbuncle, or a septic wound, or developing as the sequence of a septicæmia or a pyæmia, of course makes clear the character of the joint lesions and establishes their etiology. These are not the cases, however, in which it is difficult to make a diagnosis, nor do they represent the largest number of polyarticular affections. The more chronic the process the more difficult it is to get at its etiology, and the less clear and sharply defined are its symptoms.

In seeking for the cause of these more obscure and chronic polyarticular infections careful inquiry must be made into the venereal history, as it is probable that the prostate and seminal vesicles in man and the endometrium and tubes in woman are often a source of general infection after a chronic gonorrhœa has become established. Chronic suppurative processes which are located in other parts of the body and which owe their origin to various causes must be sought. Middle ears in children and adolescents deserve attention, and so also do the crypts of the tonsils, which frequently contain infective material buried deep in their crevices, such collections acting as reservoirs from which not only repeated local inflammations take their origin, but to which also general infections may be traced.

Pyorrhœa alveolaris is said sometimes to be a source of infection in these polyarticular cases. In these patients it is difficult, indeed impossible, to lay the blame upon any one organism, as it would be practically impossible to plate out all the organisms that may be found in the strippings from an old gonorrhœal prostate or from the crypts of the tonsils. Nevertheless, it is probable that in cases where the infection is derived from such infective reservoirs it is the toxins absorbed from these sources which do the damage, and not necessarily the organisms themselves. That there are attenuated members of a large number of the common bacterial families which are capable of producing local inflammations in the joints, of very slight severity and generally monarticular in distribution, has been demonstrated recently by Fayerweather, who worked with tissues and fluid removed from such joints in the human subject. Inoculation into animals repeatedly gave the same lesions noted in the human subject, and it was possible to keep the organism obtained from the subserous tissues of the patient intact and in pure culture after passing through the joints of several animals. This work has quite conclusively shown that many

of the mild, monarticular affections of the joints may be due to low-grade infections.

Symptomatology and Course of the Disease.

The characteristics of an infection in an articulation are subject to wide differences, but in this respect there is nothing peculiar about arthritic processes, for, as is well known, the exanthemata, for example, appear differently according as the infection is a severe or a mild one. In the typical acute case the onset is sudden, without prodromes of any sort. Occasionally it seems to be associated with exposure to draughts or to becoming wet or cold. At other times the attack will come on in the night without any warning, or the patient will rise in the morning feeling a little stiff in a certain joint or joints, and, before many hours, will be entirely incapacitated. Stiffness and lameness, followed immediately by severe and rapidly increasing pain, early development of swelling, great tenderness to pressure, and restriction in motion, passive or active, with increased surface heat and redness, are the initial objective signs. These are associated at times with an increase in the bodily temperature and invariably with an elevation of the pulse rate. Sometimes these last two symptoms seem disproportionate to the severity of the local signs. Very early in the course of the trouble additional joints may become involved in rapid succession. At times these may be only transiently affected, and, although polyarticular at the start, the disease may focalize itself upon some one large joint and remain there permanently. As a general rule the joints which become involved in a case of infectious arthritis become so in a much more rapid sequence than is the case in the non-infectious forms of arthritis. The typical acute case is such as I have described, but it is not at all unusual for new joints to become affected at much longer intervals than is the case in the more acute types.

The appearance of the affected joints is somewhat different from the appearance of the joints of that other most closely related form of arthritis, viz., the atrophic. The swellings have about the same distribution in both cases, the two processes involving the synovial membranes in both instances, but in the infectious type the infiltration of the capsule is so much more diffuse that the swelling has the appearance of being more tense and the skin seems more tightly drawn over the capsule than in the atrophic cases, where the capsular thickening is distinctively of the villous type. (Fig. 213.) The joints are apt to be simply flexed without subluxation, and the skin is bluish-white in the more acute stages of the trouble. When the process has subsided, the color of the skin returns to a normal state and the swelling disappears, but the deformity remains. If the two diseases are compared in their corresponding stages it will be found that there is less atrophy in the infectious than in the atrophic form of arthritis. For example, where the finger joints are involved, there is

very little atrophy of the interossii, which is a conspicuous feature of the atrophic type of arthritis. (Fig. 214.) Another sign which is of assistance in recognizing the infectious form of polyarthritis is the fact that the atrophy which is present in the cartilage of the atrophic cases, and which reveals itself by causing the tissues at the line of the joint to recede, gives to the joint the ap-

FIG. 213.—Photograph of a Patient in whom there are Polyarthritic Lesions. Note the capsular thickening of the knees and also of the smaller joints of the tarsus and the ankles. This is a photograph of Still's disease, but it represents very well the gross appearances of the infectious type of arthritis in these joints. (Original.)

pearance of being thinner along the line of the articulation than on either side of it. In the infectious cases, in which the cartilage is rarely disturbed, and, when it is, in a manner very different from that observed in the atrophic form of disease, no such appearance is visible at the joint line at any stage in the progress of the disease.

Any or all joints may be involved. In the monarticular types it is usually

a large joint, the knee rather more frequently than any other; then, perhaps, next in frequency come the hip and elbow. In the polyarticular types the small joints of the fingers, more frequently the second row of phalangeal and the metacarpo-phalangeal joints, are involved, and almost invariably along with these the carpal articulations. Then follow, in the order of frequency, the knees and feet, the elbows and shoulders, the spine and the hips, and, last of all, the jaw.

As in paralytic affections the neurologist recognizes certain group types of paralysis, so in these joint affections it seems as though there were group types of joint involvement. So common is the polyarticular affection of the

Fig. 214.—Photograph Showing (on the right-hand side of the picture) the enlargement of the Second Row of Phalangeal Articulations due to Capsular Thickening, and the Deformities of the Fingers due to Contracture of the Flexor Tendons. Contrast with the subluxations (left-hand side of the picture) seen in the atrophic lesions of the hands in advanced stages of that disease. (Original.)

feet in gonorrhœa, with practically no other joint involvements, that it would almost seem as though this were an entity by itself.

Again, we frequently see the entire spinal column concerned in an infectious ankylosis, and not another articulation in the body implicated.

The same objective signs are present as were noted above, the particular joint involved not exerting any special influence upon their character. The nature and severity of the infection, however, do exert a material influence upon these external manifestations of the disease. As regards the feet, for example, it is very likely that, in the common or gonorrhœal form of infection, the metatarso-phalangeal articulations, particularly those of the great toe and its two nearest neighbors, will be the parts involved. These joints are generally

much swollen, bluish-red in color, and tender to pressure and to movements, whether active or passive in character, and the entire foot shows a great tendency to clammy perspiration. There is also another part of the foot which is very apt to be affected in this type of arthritis, viz., the point where the plantar fascia is inserted into the os calcis (Fig. 215.) At this point there is great tenderness, and with this condition there is sometimes associated an inflammation of the bursa which is located between the back of the os calcis and the tendo Achillis. Whenever an attempt is made to move the foot on the mediotarsal joint a good deal of muscular spasm is usually elicited. This spasm of the muscles, combined with tenderness over the plantar surface of the os calcis and with the swollen, tender great toe, causes the patient to assume a very awkward, painful gait, and is almost always significant of a polyarthritis of

Fig. 215.—Radiograph of the Foot, Showing Spur on the Base of the Os Calcis and a Smaller but Characteristic One on the Dorsal Posterior Surface of this Bone similar to that shown in Fig. 218, which, however, is due to a different cause. (Original.)

the foot of gonorrhœal origin. It must be remembered, however, that other infections may be responsible for the same phenomenon. It is in these arthritic cases of gonorrhœal origin, particularly the more chronic of them, that spur formation is noted. This lesion is due to the long-continued irritation of the joint structures by the infective organisms or by toxins which they produce, and also by the irritation caused by simple use of the articulations when they are in an inflamed condition. (Fig. 216.) The favorite situations in which such a spur is formed are the plantar surface of the os calcis, the back of the same bone just above the insertion of the tendo Achillis, the superior and anterior surfaces of the astragalus, and that part of the scaphoid where it overlaps the internal cuneiform.

Such an arthritic affection in the feet is more often bilateral than unilateral. Except in those instances where the infection is very general in its distribution

over the joints of the body, and especially where it is of a somewhat virulent character or where the individual attacked is particularly susceptible, it is a general rule that, when one or two large joints become involved, the small ones are exempt. The infections such as I have just described in the feet are slow in their development and are not commonly ushered in by an acute onset. In the larger joints there are great capsular thickening, heat, redness at times, and great tenderness, as a rule, both to pressure and to passive motion. The infiltration of the capsule comes so early and develops so rapidly, and the synovial tissues become so thick, that it is sometimes difficult to determine just how much fluid is present in the articular cavity. In most of the larger joints

Fig. 216.—Radiograph of the Foot, Showing Spur on the Plantar Surface of the Os Calcis at Insertion of the Plantar Fascia, also one at Posterior Surface of Os Calcis at Insertion of the Tendo Achillis. The case was one of gonorrhœal arthritis. (Original.)

which I have opened—joints which were the seat of a gonorrhœal infection—the capsular infiltration has predominated over the dropsical effusion into the cavity of the joint. Whatever fluid is present in these cases is generally turbid and not the clear straw-colored synovial secretion of a traumatic synovitis. There are often fibrinous flakes or clots floating in it. In the knee and elbow joints when attacked by this infection there is some deformity which develops somewhat early and is almost always characterized by flexion. The deformity is apt to become permanent unless active measures are taken as early as may be to prevent the formation of adhesions, for adhesions produced by gonorrhœal toxæmia are extremely tenacious, apparently because the organism of

this disease is capable of exciting connective-tissue proliferation to a very pronounced degree. (Fig. 217.) In the wrist and tarsus there is a similar tendency toward deformity; in the former it partakes of the character of simple flexion, in the latter of plantar flexion or extension. Where so many small bones are concerned and complicated articulations exist, prevention of adhesions is a much more difficult matter, and hence great stress should be laid upon the importance, for the maintenance of functional power, of keeping the inflamed wrist or ankle in a good position. This is also true of the elbow. (Fig. 218.) In the hip, deformities in the direction of flexion and rotation are apt to occur, and here

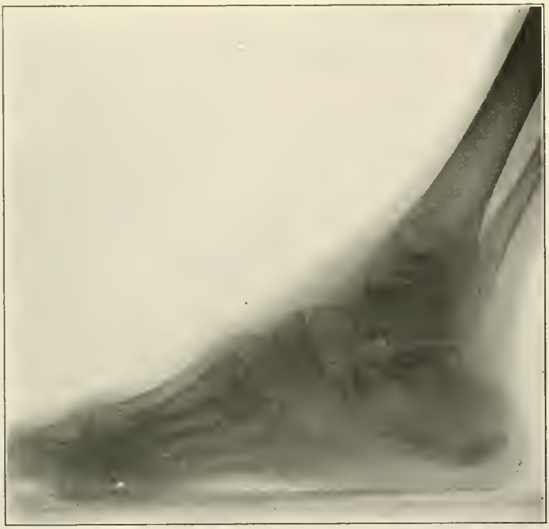

Fig. 217.—*x*-Ray Picture of Ankle Belonging to the Patient Shown in Fig. 219. Note the capsular thickening without any bony involvement. (Original.)

again the importance of maintaining the inflamed part in a good position (as regards future functional power) must be kept constantly in view, as no amount of manipulation at a later date is likely to secure much mobility if the infection has been of a severe character.

In the case of the spine (Figs. 219, 220, and 221) the characteristic feature of an infectious arthritis is to be found in the fact that it does not confine itself, as is true of some of the other diseases which have spinal symptoms, to a small segment of the vertebral column, but attacks the whole or a greater portion of it, and at once. There is no tendency to the formation of a kyphos, as there

is no destruction of the vertebral bodies. There is occasionally a list of the entire column in one or the other lateral direction or forward, and there is almost invariably a fixation of the ribs so that the respiratory excursion of the thorax is very slight and breathing is almost wholly diaphragmatic. In the later stages of the process the intervertebral discs undergo atrophy.

Infectious processes in the shoulder are not at all common, though stiff shoulders form quite a fair proportion of the joint lesions which one sees. These,

FIG. 218.—Radiograph Showing Capsular Thickening about the Elbow, with formation of adhesions between the trochlear surfaces of the humerus and ulna. (Original.)

however, are mainly cases of subdeltoid bursitis and other traumatic periarthritic changes in this region.

In the foregoing discussion only type cases have been referred to, as it is impossible to distinguish the various bacteriological causes for such symptoms from their clinical signs alone, and often bacteriological study would not prove any more conclusive, as many of these agents are not themselves present in the joints, and when they are they are not there in sufficient abundance in the fluids of the joint to be readily detected. Furthermore, it is rarely necessary or sufficiently desirable, in order to learn what the specific organism is, to open the joint and remove some of the synovial membrane for bacteriological study. What is essential for treatment and prognosis is to be able to recognize,

from the clinical phenomena, that one is dealing with an infection, and evidence is accumulating which will make it possible to establish distinctions of this nature. As our knowledge increases, we shall doubtless be able not only to say with positiveness that the process under observation is of an infectious nature, but also to specify the particular kind of organism to which the infection is due. As a further result of this knowledge it will then also probably be

FIG. 219.—Back View of Infectious Spine. No motion. Rounded back; no kyphosis. Fixation of ribs. Patient developed pulmonary tuberculosis, probably due to imperfect aëration of lungs. (Original.)

practicable to vary the treatment within certain limits in accordance with the differences in the etiological factors. Even at the present time it is known empirically that certain joint infections are satisfactorily treated by prepared sera, and doubtless the future will show greater advance along this line. It has long been recognized as a fact that the superposition of one infection upon another often effects a cure of the symptoms dependent upon the original infection.

Pathology.

The tissue changes which result from infectious processes in the joints vary within wide limits. These processes affect, under some circumstances and in

varying degree, all the structures going to make up the articulation, but the synovial membrane is the part primarily concerned. It is only in the most severe and advanced cases that the cartilage is involved, and still more rarely the bone. The amount and character of the fluid which accumulates within the joint are subject also to great variations. In the milder cases the capsular infiltration is slight and the fluid present in the cavity of the joint is in considerable excess, whereas the more severe the infection the more pronounced is the capsular infiltration and the less conspicuous the fluid in the

Fig. 220.—Side View of the Same Patient. (Original.)

articulation. Except in the less severe types of the general polyarticular infection the villi of the joint are not much hypertrophied, and when they are hypertrophied the fringe is, as a rule, shorter than that seen in the atrophic form of arthritis and is not so friable, because the inflammatory exudate which infiltrates the tissues is of a denser character. The tissue immediately beneath the synovial membrane is abundantly infiltrated with round cells, and this infiltration extends back a considerable distance into the subserous tissue, crowding out the normal fat and stimulating a proliferation of the connective tissues, as a result of which there are a great many epithelioid cells and new-formed

blood-vessels. The synovial covering becomes eroded in spots of greater or less extent, permitting these proliferating surfaces to come in contact with one another and thus favoring the formation of those firm adhesions which char-

FIG. 221.—Radiograph Showing Atrophy of Intervertebral Discs. Thickening of the posterior ligaments; absence of any lipping of the cartilages, which is the characteristic of the hypertrophic lesions in the spine. (Original.)

acterize some of these joint infections. In the severe cases the infiltration of round cells extends back as far as the fibrous portion of the capsule, there is also often considerable œdema in this tissue, and the fibrous and synovial portions of the joint capsule do not readily move one upon another, but are adher-

ent. As has been said, this process may extend beyond the synovial tissues and destroy the surface of the cartilage in places; it may even, in rare instances, extend deeper still, viz., into the bone. These are, as a rule, suppurative cases, and in my experience they have been due to the pneumococcus or the streptococcus. The finding of bacteria in the fluids of the joint is exceptional, but examination of the deeper layers of the synovial membrane will often reveal their presence, not only in the type of inflammation described by Schueller under the term "villous arthritis," but also in some of the monarticular infections.

Treatment.

For convenience and clearness I will discuss the treatment under the following heads: Drugs, dietetics, mechanics, and operations.

Treatment by Drugs.—Except for the possible entity known as acute articular rheumatism, the drug treatment of which seems to possess something of a specific character, there is little to be said. The text-books on general medicine should be consulted in reference to this. The general practitioner sees these cases and treats them best. The administration of the salicylates in small doses (0.30 to 0.50 gram—5 to 7 grains), to be taken at short intervals, seems to control the pain which accompanies the subacute stages of many of the infectious arthritic processes, but this remedy proves detrimental if it has to be kept up for any considerable length of time.

Dietetic Treatment.—In the matter of regulating the diet no attention should be paid to theoretical antirheumatic regimens. The exercise of a little common sense, after careful consideration of the individual case, will bring the best results. If there are evidences of toxæmia or of the digestive disturbances usually associated with it, the diet should not be heavy, but should be nutritious and not given in too large amounts. It is better to give frequent feedings and small amounts of food at each time. There is no object to be attained by cutting out the sugars, red meats, etc., unless these articles of diet obviously produce in the individual case an exaggeration of the symptoms in the joints or cause gastric or intestinal fermentations. The function of the kidneys should be stimulated by the ingestion of plenty of fluid (three to five pints) in the twenty-four hours; the bowels should be kept free by some mild laxative if necessary; and the eliminative functions of the skin should be encouraged by frequent bathing and rubs with dry salt. If the appetite wanes it should be braced preferably by some bitter tonic, as nux vomica or the compound infusion of gentian. After the acute phase of the disease is over, the affected joints should be given stimulating baths. These, combined with massage and mechanical exercises (Zander) and vibration, will aid in restoring normal conditions in the joints.

Treatment by Mechanical Means.—During the more acute stages of the dis-

ease, fixation in some form will relieve pain by putting the joint at rest, and, if it is not kept up for too long a time, it will not favor ankylosis, but will, on the contrary, if properly used, assist in securing the greatest amount of mobility possible. Split or removable plaster-of-Paris or celluloid splints are most serviceable for this purpose. Where there is a tendency toward deformity, fixation should be employed to check its progress as well as to remove, so far as this may be possible, that which may have already occurred.

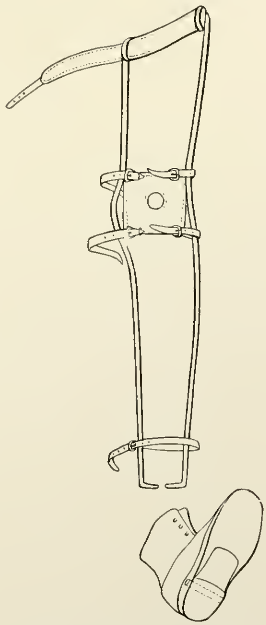

FIG. 222.—Caliper Splint. (From Bradford and Lovett's "Orthopedic Surgery")

In the contracted knees, "caliper" splints (Fig. 222), either as an aid to locomotion or as a corrective force applied to overcome deformity, will be found of great assistance.

Operative Procedures.—In some cases operative measures need to be employed. Such procedures are in the nature of manipulations to restore motion and correct deformity, or they may be arthrotomies, which have for their purpose the thorough removal of inflammatory products and the restoration of the joint surfaces to an approximately normal condition. The manipulations are chiefly applicable to such joints as the knee and the shoulder, as these articulations more easily permit of the restitution of considerable degrees of mobility. In such joints as the carpus, tarsus, elbow, and hip it is very difficult to secure motion. Correction of deformity should always be accomplished after the stage of progression is passed; and this may sometimes be secured by *brisement forcé*, provided the resort to this measure shall not have been too long delayed. But if this procedure prove unsuccessful, osteotomy or excision will generally secure the desired result. Arthrotomies, in properly selected cases, are very serviceable. A villous condition of the joint capsule which shows no sign of undergoing absorption after the lapse of a reasonable interval of time, should be dissected out. Often the presence of inspissated fibrin is a source of continued irritation to a large joint, and the removal of this material opens the way for a degree of improvement which could not otherwise take place. A very considerable amount of the synovial membrane may be dissected out without danger of impairing the mobility of the joint, as this structure, in common with many other serous membranes, has the property of repair to a remarkable degree.

Certain of the more severe infections entail so much destruction of opposing cartilaginous surfaces of the patella and femur or tibia that adhesion will be found to have taken place between these surfaces, while everywhere else the surfaces of the joint will be found free. In such instances there may be a little motion in flexion of the tibia, but this is usually due to the yielding of the tendon of the patella. When this is found to be the case it is at times justifiable to pry off the patella through a lateral incision and then to introduce from an ounce to an ounce and a half of sterilized oil in the cavity of the joint. This will sometimes prevent readherence of the joint surfaces and will secure good function. The establishment of an artificial or false joint by operation should not be practised upon the knee joint in these conditions; for, if *brisement forcé* and arthrotomy fail to secure mobility, an erasion of the joint, with the object of correcting deformity and securing an ankylosis, will give a better functional result, though perhaps less brilliant, than can be obtained by securing only twenty-five to thirty degrees of motion by the Murphy operation.

The arguments against a stiff straight knee are based more upon sentiment than they are upon any functional superiority of the pseudarthrosis. In the case of stiffness of the hip joint the operative establishment of a pseudarthrosis is a perfectly proper procedure, because in this situation less motion will permit of functional use without joint strain than in nearly any other articulation of the body. In the case of the elbow joint, if the surgeon has failed, during the acute stage of the infectious process, to maintain the joint in a position suitable for function, or if he has failed to secure enough absorption of the capsular thickening to yield satisfactory motion, an operation for the establishment of a pseudarthrosis or a formal excision, particularly the latter, should give good functional results. In this joint a great deal depends upon whether the cartilage is eroded by the infection and also whether there is any considerable destruction of opposing synovial structures. The surgeon is often called upon to see the patients who have suffered from some one of these infectious articular processes long after the affair is over—*i.e.*, at a time when the material infiltrated into the joints has been absorbed, and when only the contractures which have resulted from this capsular thickening remain. These contractures usually involve the knee joint more notably than any other joints; the posterior part of the capsule undergoing a certain amount of shortening and the hamstrings contracting in a compensatory manner, while the articular surfaces of the cartilage remain intact and the patella movable. *Brisement forcé* will be unsatisfactory in such cases, for even though, with the aid of a general anæsthetic, the joint may be forced into complete extension, it will recontract again so soon as the force or the restraining bandage or splint is removed. In these cases careful tenotomy of the hamstrings, or of such of them as seem most contracted, will relieve the contracture permanently, retention in extension splints being necessary for only a very short period.

The spurs of bone which develop in the neighborhood of the joints in consequence of the irritation caused either by the infective organisms or by the toxins which they produce, constitute another of the sequelæ of an infectious arthritis which may require surgical treatment. These spurs may occur about the acetabulum or the glenoid cavities or upon the olecranon and coracoid processes of the ulna; they may also occur over the superior surfaces of the smaller tarsal articulations and in the region of various bursæ. In the latter case it may be assumed that some antecedent inflammation of the bursæ themselves has extended to the bone which they serve to protect. The bursa which is more often concerned than any other is the one which is located just in front of the tendo Achillis, in which region a bony spur not uncommonly develops. The necessity for removing these spurs will arise when they interfere mechanically with the function of the parts concerned, and provided, of course, that the indications all point to a cessation of the activity of the infective agent upon which a continuation of the inflammation depends.

As yet, nothing has been said regarding the operative treatment of the fulminating types of arthritis. It requires surgical experience and judgment to know when to interfere in these cases, but, once that decision has been arrived at, such interference should be very radical. These remarks apply, as a matter of course, to the suppurative joints.

Joints which are the seat of an acute suppurative inflammation of the gonorrhœal type sometimes do better if they are incised and washed out with hot saline solution and then closed tightly. By this procedure the joint is freed from the presence of irritating toxins, and the likelihood of further erosion of the serous surfaces—the necessary result of which will be the formation of adhesions—will be lessened. The time when the measures suggested should be executed is during the first few days of the infection of the joint in cases which are obviously progressing. They are more particularly helpful in the knee joint, because of the simple character of the synovial pouch; and instead of a single cut the surgeon should make two lateral incisions, which will thus permit the irrigating stream to go through from side to side. Manipulation of the joint, while the patient is under the influence of a general anæsthetic, should be practised as soon as possible after the incision has healed—as early, for example, as immediately after the stitches have been removed. In the treatment of suppurating joints, Mayo's method of dividing the patella, flexing the leg, and thus exposing the joint cavity, is sufficiently radical, but is none too much so in the profoundly toxic streptococcus infections. It is the writer's belief that prompt amputation in such infections will save more lives than any of the radical but yet more conservative measures.

Good results are being reported in many of these arthritic processes from the employment of inoculations with antistreptococcic serum. It is not likely that all the infections are by members of the streptococcus family, but it is so

often impossible to get at the true bacteriological cause that we are obliged to employ this serum in a somewhat hit-or-miss fashion. Nevertheless, the employment of the antistreptococcic serum has been found to be valuable in many infections, and especially where it is composed of a number of strains of bacteria of different degrees of virulence and toxicity, as some of these sera are. Brackett has reported some favorable results of this treatment in this country. The most that can be said at present is that the outlook seems promising for the development of sera which shall be able to counteract the effect of the toxins acting locally in joints and producing more or less destructive lesions. The application of Bier's passive-congestion treatment in the acute stage of the infectious arthritides has received very favorable consideration, particularly abroad. The writer has used it only in a few gonorrhœal joints, where it did seem to relieve pain, but did not materially shorten the course of treatment or lessen the formation of adhesions, which is such a disagreeable feature of these joint infections. In the subacute and chronic cases it has been of no value. (Details regarding the Bier treatment are given in the next article.)

II. ATROPHIC ARTHRITIS.

(Rheumatoid Arthritis.)

Etiology and Nature of the Disease.—This form of arthritis has been given this name because of the atrophy of the cartilage which is such a constant as well as such an early sign of the presence of the disease. This one fact alone, which is easy of demonstration in the majority of instances and is subject to very few exceptions, enables one to distinguish it easily from the infectious arthritis, which has already been described, and from the hypertrophic arthritis, which is soon to be described. It is essentially a disease of youth and middle age, and manifests itself in women more frequently than in men. It seems often to be associated with nervous shock and emotional conditions of one sort and another, or with pregnancy, particularly when this latter state has been of frequent occurrence and the intervals have been short. Care and responsibility without adequate vacations seem to stir the disease into activity. Rarely does one find a history of previous attacks of "rheumatism" or of some other infectious process before the beginnings of the disease manifest themselves, and, when one does, it seems probable that the depression of the general system through the infection induced a disturbance in metabolism which declared itself in the form of atrophied bone and cartilage and villous thickenings in the synovial capsule. It almost, if not quite, invariably takes the form of a polyarthritis, giving the first indications of its existence in the joints of the carpus or phalanges. The metabolism of the organic and inorganic salts of the ingesta and egesta in these cases shows that during the active stage of the disease lime salts are lost from the body in a much higher ratio than they are ingested,

and. inasmuch as the larger proportion of lime in the body is in the bones, it seems only natural that they should be less dense than normal healthy bones. It has been observed that this condition of physiological loss in lime content has been superseded by a return to the normal balance as soon as a cessation of the symptoms and an improvement in the local condition in the joints have taken place. These facts go far to prove that some disarrangement of the chemical processes within the body is at the bottom of this disease.

In England there are many who believe that the condition which we are now considering is only a stage in the development of a certain kind of arthritis, and that the type of articular inflammation soon to be cited as the hypertrophic is the second stage of this arthritis—*i.e.*, that it follows the stage of atrophy. McCrae, in a recent review of the subject in this country, entertains practically the same opinion. To support such a view it would seem to be necessary to show that the lesions of the hypertrophic stage were preceded, in a considerable number of instances, by evidence of atrophic changes, or, in other words, that the atrophic lesions were followed, in course of time, by the hypertrophic changes. As a matter of fact, coincidence of the lesions characteristic of both diseases in the same patient is extremely rare. Even this explanation is capable of another interpretation, one which is not unreasonable and which has a certain amount of evidence to support it, although the complete proof is not as yet at hand. It may, however, be positively affirmed that there exists no evidence to prove that either of the processes gives place to or is converted into the other, and that etiologically, as well as pathologically and clinically, they have nothing in common except their chronic character. Attempts to explore the lesions of atrophic arthritis for the purpose of demonstrating the presence of bacteria—as, for example, by examining the fluid aspirated from such joints—are misdirected, because, where care is taken to include in this classification only joints affected by atrophic changes in the cartilages and bones, the bacteriological findings are negative. In fact, in few such cases is there fluid present in sufficient abundance to justify aspiration with any hope of finding micro-organisms. The difficulty of recognizing the presence of fluid in a joint in a case in which there is much villous change in the synovial membrane, is considerable if one is not accustomed to palpating such joints.

Clinical Course.—After a consideration of the etiology, a careful study of the progress of the disease in the joints must be undertaken. The onset is insidious and slow, the disease usually commencing with stiffness and swelling in the smaller articulations of the phalanges, and attacking, one after another, a considerable number of joints, large as well as small, but manifesting a great aversion to the spine. In the vast majority of cases the disease, if left untreated, slowly progresses, continuing for a number of years in a condition where new joints may become involved at any time or old ones become freshly af-

fected. There is rarely much acute pain or any more constitutional disturbance that might not just as properly be ascribed to the long-continued effects of a crippling disease as to any constitutional complication. In the more pronounced types of the disease the patients sometimes appear anæmic, but examination of the blood, in a goodly number of such cases, has shown that there was a rather high count of red corpuscles with a high carrying capacity for hæmoglobin. Enlargements of the lymph nodes are not unduly comm n in such patients, and cardiac complications do not occur with abnormal frequency. The skin, except as it may be somewhat stretched over the enlarged joints, presents no peculiarities in the early stages, but in the more advanced conditions

Fig. 223.—Shows the Spindle-shaped Swelling of the Second Phalangeal Articulation of both middle Fingers and also of the Metacarpo-phalangeal Articulations in both Hands. (Original.)

it is thin, shiny, and parchment-like. The surface temperature is not increased, and there is a notable absence of the congestion seen in the infectious cases. There is sometimes abnormally abundant, clammy perspiration over the palms of the hands and the soles of the feet, but this is not peculiar to atrophic arthritis, as it is seen in many other conditions. The swellings which are so characteristic of the early stages of the disease are spindle-shaped (Fig. 223), but differ from those observed in infectious arthritis in the following respect: In the swellings of the latter disease the infiltration of the capsule involves the fibrous as well as the synovial portions, and therefore the swelling has a more tense appearance and feels harder than that commonly observed in atrophic arthritis. The thickened synovial villi are seldom accompanied by any excess of fluid in the

joint, and the articular swelling is therefore not so firm and tense on palpation. There is seldom much tenderness when the parts are pressed upon, and the joints are not particularly sensitive to manipulation in the early stages; there is also not much restriction in motion at this time. As the disease advances and the cartilage becomes eroded (Fig. 224), deformity may appear and motion may become more difficult and more restricted. Atrophy of the mucles in the neighbor-

Fig. 224.—Shows Loss of Cartilage Complete in the Second Phalangeal Articulation of the Ring Finger of the right Hand and of the Little Fingers of both Hands, with a diminution in the thickness of the cartilage in the same joints of the index and middle fingers of the right hand and the middle and ring fingers of the left. Compare the thickness of the cartilage in the terminal phalangeal articulations. (Original.)

hood of the affected joints is an early symptom. As the condition progresses, atrophy takes place in the joints themselves, and the cartilage becomes so thinned that it occupies less space between the bones than usual, and this shrinkage is shown by an atrophy of the tissues immediately over the line of the articulation. The deformities which are characteristic of this form of arthritis are luxations due to the atrophy of the cartilage and the pull of the muscles which

are attached to the proximal ends of the distal members of the joints. (Fig. 225.) Such deformities are most notable in the second row of phalangeal articulations in the hands, and in the knee joints. The wrists, feet, and ankles rarely show much, if any, deformity; the hips and the spine most rarely of all, because they are so infrequently involved. There is sometimes a little flexion at the wrist, and the ankle is often considerably pronated and rigid owing to the presence of erosions between the tarsal bones. The elbows are quite frequently concerned, and they are usually flexed to a considerable degree. In the most advanced cases only does complete ankylosis occur in the simple joints. In the complex joints, as those of the carpus, tarsus, and elbow, ankylosis, complete or nearly so, is not uncommon. This is rarely a true bony ankylosis, but is a fibrous union, which, however, is very firm. If the disease is not arrested great emaciation and pallor may ensue, and every joint in the body may become ankylosed. The changes in the skin in these advanced types are very pronounced and most distressing, the entire surface of the greater portion of the body becoming covered with very thick, crustaceous scales, which tend to recur as fast as they are removed. Milder skin lesions consist of white plaques with occasional brownish mole-like spots scattered about, usually in parts of the body exposed to the air and sunlight. Decubitus is a common and distressing complication. The nails partake of the changes going on in the skin; they become cracked and striated and often exfoliate as the epidermis is seen to do. Such lesions are significant of the more aggravated types of the disease. If it is arrested, the synovial thickening becomes slowly absorbed, and the motion of the joint, provided the cartilage has not been eroded too much to permit of it, is restored approximately to the normal. If the cessation of the process did not take place until after deformity had occurred, there is no reason to suppose that this deformity will be

Fig. 225.—Shows a Sharply Eaten-out Spot in the metacarpo-phalangeal articulation of the ring finger; also thinning of the articular cartilages between the phalangeal joints. Similar atrophy of the interarticular cartilage is shown in the carpal bones. Terminal and second rows of phalangeal joints show but little cartilaginous atrophy. (Original.)

overcome. A certain amount of restoration of motion and improvement in function, as well as diminution in swelling, is to be expected.

Pathology.—The pathological changes noted in the tissues of the joints concern the synovial membrane, the cartilage, and the bones. Much study has been devoted to the central nervous system in an attempt to ascertain the cause of this disease, but no characteristic changes have been noted in this part of the body. There are also no lesions of the viscera that are of any significance. There is no support for the theory that there is some trophic lesion of the central nervous system which is the cause of the disease. The inflammatory causation theory receives no positive support from pathology, for all the lesions which through any stretch of the imagination could be called inflammatory are of such a chronic nature that they might be caused by any local irritation, be it inflammatory or otherwise. Bacteriological examinations, both of the fluids obtained by an exploratory incision and of the tissues removed from the joints, in cases of this clinical type, have failed to show the presence of any micro-organisms.

As has been pointed out, the fluid in these joints is not, as a rule, present in any noticeable quantity and has no abnormal characteristics. Rarely is there any excess of fibrin in it, and under the microscope it does not show any evidence of being an inflammatory exudate. The villi of the joint are markedly increased in number as well as in bulk. They are velvety in appearance, are covered with serous membrane, and, as a rule, are dark purple in color. Sometimes on nicking the synovial membrane there will bulge out through the wound a cauliflower-like mass which is very friable and which cannot be crowded back into the joint.

By aid of the microscope it will be seen that the synovial membrane is markedly infiltrated with round cells. So abundant is this infiltration in places, particularly near the surface of the synovial membrane, that the structure sometimes looks as if it might be lymphoid tissue. The fringes will be cut in various planes, and great numbers of them will be seen in every microscopic field. Back from the immediate surface of the synovial membrane the infiltration becomes less and less dense and more and more fatty. The nutrient stalk comes in through the centre of the neck of the villus and ramifies through it. After the process has gone on for a certain period of time the density of the infiltration with small round cells becomes less and less marked, the blood-vessels become less numerous, and the larger ones show some endarteritis, possibly a compensatory one, but more probably a part of the process, for it is not seen in any other form of arthritis, whether the inflammation has been in progress for an equal length of time or not, and whether there has or has not been the same amount of restriction in function. Occasionally bone and cartilage have been found in these fringes—a manifestation of tissue metaplasia. The changes in the synovial membrane which I have just described precede the

changes in the cartilage and bone. The changes in the cartilage come next in order of frequency and first in the order of clinical significance. There is a general thinning of the cartilage, associated with a loss in the sheen on its surface and a beginning striation. If this goes on, further erosions will occur on the surface of the cartilage. These erosions, which vary in size from the head of a small pin to a surface as large as a silver quarter of a dollar, may develop in close proximity to each other with small bridges of attenuated but intact cartilage separating the eroded islands. When recovery takes place these eroded areas are covered over by fibrous tissue more or less densely infiltrated with round cells. The bone is the last to be affected, and, structurally, it receives the least damage. As has already been stated, when I had occasion to speak of the chemical changes ascertained by a study of the metabolism in this form of arthritis, there is a loss in the calcium content of the bones. The gross appearance of the bone indicates that the intertrabecular tissue has been replaced by fat and fibrous tissue, principally the former. The trabeculæ stand out on the cut section of the bone like fine wires. On section, not only do the trabeculæ seem smaller, but they seem fewer in number and irregular in their branching. The nuclei of the bone cells do not stain as well in the lacunar spaces as in normal bone, but there is no evidence of necrosis.

Treatment.—Treatment is best considered under two heads, viz.: first, general; second, local. Under the head of *general treatment* it is necessary to consider diet, because one of the first things these patients will inquire about is their diet, and very often dietetic treatment is about all they will have had. The treatment in question is usually based upon the supposition that the condition is rheumatic in its nature, in the old acceptation of that term. Very frequently these patients will be found to have been practically starved, and their asthenia and emaciation, as well as their anæmic condition, will be found to be due to their lack of proper nutriment. The digestive functions in persons with this form of arthritis are not materially disturbed, and, as it is in no sense an inflammatory disease, it is not necessary to put them upon an antirheumatic diet. In fact, there is every reason for not doing so. A wholesome, generous diet that contains all the elements of a normal person's dietary, provided it is relished and digested, will be found to yield the best results. Medicinally, there has been great misapprehension with reference to treatment. The rheumatic hypothesis as to causation has here been largely responsible for the errors in treatment, and these errors have been positive ones and not simply negative. It is a positive harm to these patients to be drugged with salicylates and iodides for long periods of time, as it disturbs their digestion and adds to a condition in which malnutrition is a characteristic, a condition in which what food is offered is loathed, if not actually rejected. Besides this, these remedies have not a single alleviating effect upon the course of the disease or its symptoms. In the painful cases an occasional dose of salicylate in the form of as-

perin will be helpful for the time, but even this fails of its purpose quite as often as it succeeds. Morphia is rarely needed and should, as a matter of course, be avoided. When pain is very severe, codeia will give some relief if it cannot be attained by mechanical means. Tonics are of value to stimulate the appetite, but it is a good deal of a question whether the losses in calcium can be made up through any internal medication. The glycero-phosphate of lime and soda and a mixture of nux vomica, sodium bicarbonate, and the compound infusion of gentian are very beneficial. Iron in some form is helpful in these cases. Attention to the excretions of the kidneys and bowels should be a matter of routine.

Under *local treatment* we have to consider massage, hydrotherapy, exercise, mechanical measures, and operation.

Massage is helpful in these cases at almost any stage, except perhaps the very first period of the attack, when the villous changes in the synovial membrane are taking place actively. Even then, if gently carried out, these manipulations do no harm and favor the nutrition of the part. This is true even when plaster splints or other protective apparatus are being used.

Hydrotherapy, when it is carried out in all the refinements of the Baruch system, or even when it is applied in the crude manner in which it can be utilized in any home, will be of assistance in promoting a cure.

Exercise, which as a rule must first be carried out by the aid of an attendant, but may later be performed through the patient's own efforts, will preserve the nutrition of the parts and help to secure ultimately for the sufferer the best possible functional power of the joint. Manipulation stimulates the local nutrition and also helps to overcome the stiffness which is caused by the prolonged inactivity of the more acute stages of the trouble.

Protection to the affected joints is beneficial in the acute stages of the disease, but it should always be of such a nature that it will not prevent the execution of the other measures described above. Plaster of Paris carefully applied in the form of light removable splints is the agent most efficient for this purpose. In some cases similar splints made of celluloid or leather may be employed. Another purpose which such apparatus serves in these cases is the prevention or overcoming of deformity, more particularly in the knees. Here the caliper splints are the most readily adjustable. These are made of light, round iron uprights adjusted to a socket in the heel of the shoe, and extending to the top of the thigh. They are furnished with a knee cap which enables one, by gradually straightening the iron side rods, to exert a considerable extension force upon the front of the knee, a force which tends to overcome the tendency to flexion so commonly seen in these cases. In using apparatus on these joints, care should be taken to preserve the motion in flexion at the same time that effort is being made to secure a correction of the deformity. The development of flexion deformity is almost always associated with some rota-

tion of the tibia, knock-knee, and subluxation. It is these two latter deformities which are hardest to overcome if they become well established.

The *operative treatment* of this disease consists in the employment of the following measures: *Brisement forcé* to overcome deformity, especially in the knees; the division of contracted tendons in the long-standing cases, combined with forcible manipulation; the making of a free incision into the affected joints for the purpose of relieving them of hypertrophied fringes; and tenotomies of contracted tendons, after the disease is spent, in order to improve function.

Inasmuch as there are commonly very few adhesions in this sort of arthritis, the overcoming of deformity is usually not very difficult, provided sufficient time has not elapsed to permit the contracture of the flexor tendons and the shortening of the posterior portions of the capsules of the joints. Moreover, when such luxation has occurred, there is little likelihood that the surgeon will be able to overcome the deformity completely. With the aid of the genuclast (Fig. 226) in the deformities about the knee, subluxation may be diminished at the same time that flexion is overcome. When the contractures are sufficiently strong to resist complete correction by a reasonable use of the genuclast, then division of the posterior tendons may be resorted to. Arthrotomy should be tried in any joint in which the degree of villous change is marked and shows no tendency to subside. The removal of the fringes takes away pressure from within the joint. This pressure, if too long continued, not only increases the impairment of the joint structures, but also, through interference with the function of large and important articulations, materially hinders constitutional improvement, which in turn exerts a decided influence upon the affected joints. The arthrotomy is generally performed through two lateral incisions which run parallel with the femur and are equidistant (about 3 or 4 cm.) from the sides of the patella, the lower third of the incision being directly over the line of the joint. After the joint has been opened the larger fringes are dissected off with scissors and the joint is washed out with sterile water. The synovial capsule is closed with interrupted silk, and the skin with silkworm gut. Drainage is generally not necessary. If flexion of the joint has existed previous to the operation it is generally better to put the joint up in a plaster-of-Paris dressing in the corrected position. Passive motion and release from permanent re-

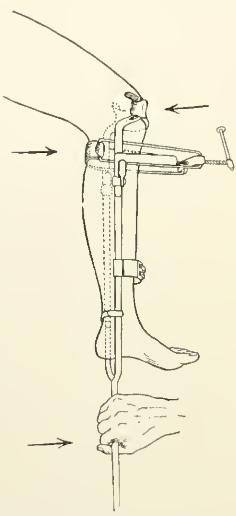

Fig. 226.—The Bradford-Goldthwait Genuclast Applied.

straint should begin when the stitches are removed, at the end of the first week. The cicatrization of the bases of the fringes prevents further swelling of the joint from villous changes, and so great is the power of repair in endothelial tissue that new synovial membrane is very quickly made to grow over the bases of the excised villi. Because of this rapid repair adhesions rarely follow arthrotomy for this purpose. There is little hemorrhage from these excised fringes.

Prognosis.—Contrary to the usual opinion the outlook for patients with this disease is not bad if the condition is recognized early and proper treatment is commenced. The patients must be made to recognize the importance of their active co-operation in the management of the case, and relief from care and responsibility, or whatever the form of nervous strain may have been which caused the trouble to begin, is a *sine qua non.* Great care must be exercised to determine what this factor was. Nervous prostration or its remote effects so often interfere with the recovery of these patients that in giving a prognosis as to the joint conditions the presence or absence of this factor must be given due weight. In giving a prognosis it is necessary to define with some degree of definiteness what is meant by recovery. It is needless to say that a simple restoration of the joint to its normal functional power is not meant, but it is beyond doubt true that, under the conditions outlined, arrest of the disease has been and can be brought about and good functioning joints secured, although evidences of the disease may be left behind, both in the outward appearance of the articulations and in the imperfections of their use. The uncertainties of our knowledge with regard to the specific causative factors which have brought about the disturbance in metabolism to which the lesions owe their origin, make it impossible to say positively that a recurrence or a relapse may not take place if the proper combination of circumstances is again brought about.

III. HYPERTROPHIC ARTHRITIS.

(Osteo-arthritis.)

In this form of arthritis we have a chronic affection which may appear as a polyarthritis or in a monarticular form. It is never as extensive in its involvement of the joints as either of the before-mentioned types may be, and very frequently we find only a single large joint involved.

Etiology.—The period of greatest frequency in the occurrence of the disease is middle and late adult life, *i.e.*, from thirty-five to sixty years. Probably, if all the lesions are included, women show more signs of the trouble than men, but the more seriously crippling lesions are noted in men. This is because in men the lesions are seen more frequently in the large joints, where

they are of more serious consequence. Among women the smaller joints of the fingers and occasionally the knees are the parts more frequently attacked. It is rarely seen in adolescent life or even in young adult life, *i.e.*, prior to thirty-five years. Constitutional disturbances in connection with it are very rare, and by this is meant that the sufferers from it are not made ill by it. They are sensible of more or less disability and suffer some pain on use of the affected joints, but are not incapacitated in any other way by the disease. It seems to be transmissible through hereditary influences to a considerable degree. A large number of people, particularly in the better classes,—*i.e.*, the well-to-do,—are able to trace the tendency to have these lesions back to a near or a remote ancestry. In this class of people hereditary influences seem to supply the underlying cause for the manifestation of the characteristic lesions, whereas in the working classes a definite history of the disease in the ancestors is more difficult to obtain, but traumatism is often closely associated with the development of the trouble, as is also exposure to wet and cold without adequate opportunity to dry off or get warmed.

The disease is of frequent occurrence in those who work at occupations in which sudden changes in body temperature are likely to occur, as among stationary engineers and firemen, and those who are employed in the "drying rooms" of paper mills and in similar situations. These men work in a hot room until they get into a perspiration and then are called out or go out, for the purpose of getting cooled off, into a room which is of a good deal lower temperature. They become so suddenly cooled that their metabolism is disturbed seriously, and this disturbance manifests itself in local changes which have characteristics common to these lesions wherever they may occur.

The traumatism or exposure need not be any one pronounced and definite traumatism or exposure; it may be the oft-repeated and slight occurrences of this sort which come in the ordinary pursuit of one's occupation. In women, particularly those who do their own housework, it is the terminal phalangeal articulations which show the lesions first, the so-called Heberden's nodes, and it is probable that the constant use of the fingers in the accomplishment of the routine duties of a housewife induce, through the slight and oft-repeated injuries to these joints, the development of the node on the borders of the articular surfaces. Repeatedly wetting the hands in hot or tepid water and then turning at once to do some other thing without giving the hands a proper drying may be instrumental in exciting the lesion. In those who sew a great deal it is common to note the greatest, sometimes the only, enlargement, upon the "thimble finger," showing the influence of a traumatism of a very definite sort as a factor in the excitation of symptoms.

In women the knees are also frequently involved, and this is particularly true of stout women. It has seemed to the writer that the frequent association of hypertrophic changes in the tibiæ and femora of fat women who have

to be on their feet a great deal was probably to be explained by the fact that such women are very apt to be a little "knee sprung," a disturbance in their statics brought about by an unconscious attempt on their part to keep their centre of gravity adjusted to changes in the distribution of their weight. The pendulous abdomen means almost invariably, in those who must stand a great deal, a flexed knee. It is not long before a flexed knee in standing becomes a flexed knee in walking, and then the pressure in the joint is materially changed and the opportunity for a slight but oft-repeated internal traumatism to the joint is present. This results in an hypertrophy of the articular cartilage, and this is aggravated in persons who are in addition flat-footed.

In laboring men the hip, the knee, the spine, and the elbow are the joints most commonly affected, and it will be frequently observed that occupational traumatism plays an important part in the production of the symptoms of which they complain.

In certain young people, particularly athletic men, one sees lesions in the joints which have the hardest use, lesions which are very similar to the lesions of hypertrophic arthritis. These are, however, closely confined to the one special joint, and this a joint which is being subjected to especially hard usage. It does not seem that in these cases there is necessarily any metabolic disturbance at the bottom of the entire process, which is simply being aggravated and brought to the surface by the local traumatism. Such lesions have been seen in the pitching arm of prominent ball-players and in the elbows of tennis-players.

Pathology.—There is but little known of the pathology of this disease, principally because it is not a mortal affection. A post-mortem study of the disease has therefore not been possible, and the opportunity to get fresh operative material in the different stages of the disease has not been forthcoming until quite recently. The terminal lesions do not obviously afford the proper basis for an investigation of the causation of this trouble, although this is all that has been used up to very recent times. Furthermore, it ought to be equally obvious that stages in the process of development of the lesions should not be studied independently of the disease as a whole. There is no difference in the character of the bone changes wherever the disease may be situated, so that it is sufficient to describe the pathology of any articulation, —as, for example, the knee,—inasmuch as this joint is the one most available for study.

There are practically no changes in the synovial membrane, except about the spurs which form at the juncture of the bone with the cartilage. About these places there are at times synovial thickenings and pannus-like formations of the synovial membrane which overlap the developing bony spurs, but there is seldom any diffuse capsular infiltration as has been noted in the synovial membrane of the infectious and atrophic forms of arthritis. There is seldom any excess of fluid in the joint, and when it is present in excess it pre-

sents no abnormal characters. The hypertrophy of the cartilage takes place along the edges of the trochlear surfaces of the femoral and tibial condyles, at which points it overhangs or projects into the joint as much as one-fourth of an inch. This projecting portion is not as hard and firm as ordinary cartilage or bone and can be easily shaved off. These spurs also form about the patella, especially at the points of insertion of the quadriceps and patellar tendons. Histologically, they consist of a very thick layer of cartilage cells arranged in columns, suggesting the arrangement seen in rickets at the juncture of the diaphysis with the epiphysis. In the more advanced stages of the disease this tissue becomes transformed into bone, oftentimes of an ivory-like density.

When the osseous ridges have formed to a sufficient degree to interfere with the motion in the joint they produce alterations in the trochlear surfaces whereby the cartilage becomes eburnized and loses its normal appearance, and in its surface deep grooves are sometimes formed where pressure from spurs has been exercised for a long time. This is seen particularly in the knee and hip joints. The spur formations are so pronounced at times in these cases that they become chipped off through the normal action of the joint or because of some special traumatism from the outside. These float about in the joint as foreign bodies, causing at times locking of the articulation. There are no alterations in the trabeculæ themselves or in the intertrabecular tissue. Not enough metabolism work has been done upon these cases to enable one to draw any conclusions as to the cause of the disease.

Symptomatology and Clinical Course.—The onset of this trouble is very insidious and varies a good deal in the severity of the symptoms to which it gives rise. At times very considerable lesions form, causing decided restrictions in the motion of a joint, with scarcely any pain. On the other hand, much smaller deposits of bone will be accompanied by a great deal of pain and disability, the location of the spurs seeming to have much to do with the amount of pain which the patient suffers.

Stiffness in the use of the joints and inability to put them in positions that were formerly easy are usually the earliest signs of the development of this disease. Pain does not manifest itself until lesions of considerable extent have developed, and the same is true of deformity and functional disability. The disease is one in which considerable time is required for the complete development of the lesions to which it gives rise, but when these have been fully established the discomfort attendant upon their development ceases, and only that which may be due to the mechanical disturbance of the affected joints persists.

Associated with these joint disturbances there are very few if any constitutional symptoms. The most notable, as well as the most constant, one is the tendency to constipation, and this seems very frequently to be associated with the exacerbations of the disease, seeming to indicate that this condition is related in some way to the failure to eliminate the waste of the body.

Certainly this hypothesis seems to be borne out in the results of treatment. Encouraging the elimination of the body waste through the excretory functions of the skin, kidney, and intestine, tends to keep these patients freer of symptoms and more comfortable in every way.

Special Symptoms.—It will be well now to take up the special manifestations of the disease as it affects particular joints.

Feet.—Hypertrophic lesions in the feet are not very common, and must be distinguished from the spur formations which accompany some of the infectious

FIG. 227.—Shows Marked Hypertrophic Nodes on the inferior border of the tibia, on the scaphoid, on the back of the os calcis, and on the inferior surface of the latter bone. (Original.)

processes, *e.g.*, gonorrhœa. The history and the physical examination, if made at the time when an infection is fresh, will generally enable one to distinguish between the two. The hypertrophic lesions in the feet are usually confined to the articulations between the scaphoid and astragalus and the scaphoid and the internal cuneiform. (Fig. 227.) In the x-ray picture they show very well and produce their painful symptoms and restriction in motion by overlapping the articulations in the feet where abduction takes place. On physical examination there is usually nothing to see, though sometimes the bony spurs are large enough to cause the skin to protrude above the customary level of the instep, often showing a difference on the two feet. The spurs are not commonly tender to pressure, nor is pain caused by passive motion. It is only when weight

is borne upon the feet that pain is produced. Motion is restricted in the mediotarsal joint, but not in the ankle joint. There is no redness, congestion, or acute swelling. The presence of Heberden's nodes or hypertrophic lesions in other articulations tends to bear out the diagnosis, though their presence is not necessary to a diagnosis. In the presence of this diathesis, pressure from tight shoes or shoes not properly adjusted to the feet is liable to cause trouble and excite the formation of characteristic lesions. In this connection it might

FIG. 228.—Shows Marked Lipping of the Patella and also of the posterior-inferior portion of the trochlear surface of the internal condyle of the femur. (Original.)

be worth while to mention the fact that in the metatarso-phalangeal articulation of the great toe hypertrophic lesions are seen occasionally, causing what is known as *hallux rigidus,* though this is oftentimes purely an irritative lesion without any diathesis behind it. The treatment of these lesions in the tarsus must be fixation during such time as the process is active. Nothing is to be gained by surgical procedures of an operative kind, a rule which holds for all acute hypertrophic arthritic lesions wherever situated.

Knee.—In this articulation one meets perhaps the largest number of crippling hypertrophic changes. The lesions are either on the femur, the tibia,

or the patella, and they are more commonly bilateral. In women they occur, as has been heretofore described, in those who are stout and somewhat "knee sprung," and are often associated with valgus. In men it is of more frequent occurrence in the laboring class, though it is occasionally seen in those who are sedentary in their habits and pursuits. (Fig. 228.) The x-ray shows bony enlargements projecting from the margins of the articular cartilage directly into the joint, and also from the periphery of the patella. This bone itself seems to be thicker and squarer than normal, and at the attachment of the large tendons spur formation is most likely to occur. The early symptoms are stiffness and pain. The assumption of one position for a long time will be found to be associated with great difficulty in getting up and about, but this soon becomes better and discomfort may leave the patient entirely for the greater part of the day. Pain at times is quite severe and is referred to the line of the joint and is rarely referred away from that point. On palpation no excess of joint fluid is discoverable, and, as a rule, there is no capsular thickening. No increase of surface temperature is present, and the patients complain very frequently of soreness and tenderness over the condylar sufaces. The patients occasionally complain a great deal of cold and chilly sensations in the knees themselves, although on examination no objective signs of cold will be noted. As the disease becomes more advanced the bony thickening will be enough to show in measurements about the joint. If the circumference of the joint be taken just above the patella and just below the patella the greatest difference will be seen in the latter measurement in comparison with the well side. There is always some atrophy of the thigh and usually some of the calf, but not so marked in either place as is the case in inflammatory joint lesions, particularly tuberculous ones. Deformity is early noticed. There is never subluxation, because muscular spasm plays no part in the deformity, thus eliminating any backward pull of contracted hamstring tendons upon the tibial head. The deformity is wholly one of flexion, and only a few degrees of that at the most—possibly twenty to twenty-five degrees. In the early stage of the tendency toward deformity it may be possible completely to extend the leg, but attempts to do so will cause pain in the joint. As has been said, there is no muscular spasm to guard the joint, so that whatever motion is preserved is wholly free. Flexion is generally complete. The existence of other lesions of this character in the same individual has, of course, a significant bearing upon the diagnosis, but there is nothing that it could with any reasonable possibility be confounded with. In treatment, fixation in a removable apparatus will quiet down the process most quickly, permitting the patient to use the limb somewhat and favoring as much as possible the correction of the deformity by aiding in the absorption of the thickened cartilage and at the same time bringing some relief from the discomfort. Almost all hypertrophic lesions are made more comfortable by fixation. If they are not, it is a hint that the surgeon may be on the wrong track in diagno-

sis. Heat always conveys a soothing sensation to these joints and should be applied frequently as a fomentation or a stupe or in the form of hot sand; or the limb may be introduced into one of the ovens which are so much in use at the present time. In the milder cases good results may be expected from the use of heat, from sweating of the part under rubber dam at night, and from the application of adhesive-plaster strapping and flannel bandages during the day, accompanied by a restriction in the amount of exercise which is employed.

Fig. 229.—Shows Marked Overgrowth of the Superior Lip of the Acetabulum, and in fact of the whole acetabular border, as is evidenced by the obscuring of the contour of the head of the bone. (Original.)

Blistering and electrical applications of various forms are employed, but are not in any sense specific remedies for the trouble. Stairs and hills should be avoided as much as possible.

Hip. Enlargements of the head of the femur or of the acetabulum, or of both, produce a condition which has been described as *morbus coxæ senilis*. It is not, however, a senile condition by any means, as a good many young adults suffer from the disease in this situation. Men have this form of hypertrophic change more frequently than women; for what reason, is not very clear. It is

more often seen in laboring men than in those whose occupations are more sedentary. In its onset there is oftentimes an entire absence of any acute suffering, the patients noting simply an increasing disability in the affected leg and that they cannot get at their feet to put on their boots as easily as usual. As there is not likely to be much deformity associated with the trouble, painless use of the limb in walking, for a considerable time after the first stiffening is noted, is usual. Restriction in motion comes on gradually, and is most marked in abduction and inward rotation. Flexion is preserved the longest and seldom is entirely done away with. Permanent outward rotation becomes established in the extreme cases. There develops gradually a limp which is due partly to the restriction in motion and partly to a little shortening which is likely to occur. Atrophy of the thigh becomes very marked as the disease goes on; atrophy of the calf occurs, but not to any such degree as in the thigh. Difficulty in sitting naturally and in getting on the feet from a sitting or lying posture, and limitation in the radius of activity because of the fatigue which accompanies slight use of such an imperfect joint, are the results attributable to this disease in this situation. Pathologically, the deposit of new-formed cartilage and bone is so distributed about the head of the femur (Fig. 229) and upon the acetabulum as to overlap and thus interfere mechanically with the motion of the joint. Occasionally a "lip" will be broken off and an osteophyte will be found loose in the joint. This, fortunately, occurs rarely in this situation. The formation of osteophytic processes extends sometimes down on the neck of the femur and even to some extent up on the side of the ilium above the acetabulum. On examination, it will be observed that the patients have a peculiar hitch in their gait, due to the shortening of their stride and to the inability to rotate the leg. Passive motions show a restriction in rotation both inward and outward, but particularly the former; there is some permanent outward rotation; flexion may be slightly restricted, but is almost invariably accompanied by a tendency to adduction in the last few degrees of possible flexion; abduction is markedly restricted. Atrophy of the muscles of the thigh and buttock, a slight degree of atrophy of the muscles of the calf, considerable thickening of the trochanter, a slight amount of shortening of the limb, and often a little flexure of the neck of the femur are the customary findings. Occasionally the disease attacks both hips at once, producing a very distressing condition. Not infrequently there is a similar process going on at the same time in the lumbar spine. The treatment of the condition, if it is to accomplish anything, must be commenced early. There is very little that can be done for the advanced cases, particularly those which occur in old persons. Protection to the joint, with a view to limiting the extremes of motion, prevents as much as possible the formation of the "lips." This is best accomplished by the application of a plaster or leather spica. For a time, crutches should be used. It is difficult to persuade patients of the necessity for these measures, because they can usually ill afford to give

up their work to the extent that the use of a spica compels them to do, but, if they will submit to the inconvenience, better function will ultimately be secured. In the extreme cases operative measures may sometimes be profitable. Excision of the joint has been practised in some cases, but the results have not been very satisfactory, because the function of a hip joint after excision is at best imperfect. Occasionally, when a bad abduction deformity occurs, a subtrochanteric osteotomy will improve the position of the leg and render walking less painful, although, of course, this procedure can give no better motions in the joint. More rarely still, a few cases will be found where the removal of the hypertrophied acetabular "lips" and chiselling off the osteophytes on the femoral head will improve the position as well as relieve the strain on the joint when attempts are made to use the limb. This can be accomplished through an anterior incision, or, better still, by making a semilunar incision along the iliac crest, turning up a flap of skin and muscle, and thus exposing the superior border of the acetabulum. The muscles can then be sutured back into place. A plaster spica applied with the thigh abducted should be allowed to remain in position for five or six weeks after the operation.

Sacro-iliac Articulation.—Museum specimens have abundantly proven the existence of hypertrophic lesions in the joints between the sacrum and the iliac bones. In some cases the bony deposit completely fuses these bones, and, although there is not a great deal of motion between them at best, still the obliteration of what there is gives rise to very considerable disturbances. The first and most conspicuous symptom is pain referred directly to this articulation and to the thigh and calf of the affected side. There is sometimes localized tenderness in a small area over the line of the joint. A slight degree of atrophy of the thigh and buttock is quite common. There is often a decided list of the trunk away from the affected side, and attempts to correct the position cause great pain. Any motion of the body involving the use of the joint on that side causes pain. Spinal motions and hip motions are usually free, though the former may be restricted; but the most characteristic signs are the pain and restriction in motion which are caused by attempts to flex the thigh when the leg is in an extended position. Such attempts render the posterior thigh muscles taut, and they in turn, when thus stretched, give rise to great pain through their pull upon the bones which form part of the articulation between the sacrum and the ilium. It will be seen also that flexion of the thigh, when the leg is extended, is not possible to the same extent on the affected as upon the unaffected side: whereas, with the leg flexed, voluntary motion of the thighs will be equal on the two sides. Fixation in a plaster spica is the only treatment which is at all serviceable, and this must be continued for a considerable time.

Spine.—Hypertrophic lesions in the spine are very common. They are described under several different terms and are often not properly distinguished from

infectious and other processes involving the spinal column or its ligaments. There is a definite deposit of bone, about the vertebral articulations (Fig. 230), of a character precisely similar to that seen in the other joints heretofore described. It

FIG. 230.—Shows Marked Lipping of the Vertebræ in the Lumbar Region. (Original.)

is oftentimes more marked on one side than upon the other, or more conspicuous anteriorly than upon either side. In the most pronounced cases the deposit appears like some plastic substance poured over the fronts of the vertebral bodies, fusing them into a more or less solid mass. The lumbar region is the part of the column most frequently affected, then the dorsal, and finally

the cervical. Rarely is the entire column involved, as is so frequently the case in the infectious processes. In fact, this peculiarity constitutes one of the chief characteristics of the hypertrophic process in the spine. Etiologically, the beginning of the disease in the spine seems most often associated with exposure to sudden changes in temperature or to having the body thoroughly wet with rain and not being able properly to dry one's self. Pain in the lumbar spine, usually described as lumbago, with pain radiating down one leg, rarely down both,—a pain which is usually designated as sciatica,—constitutes the most marked symptom. The patients have no constitutional symptoms. Coughing or sneezing causes a great deal of pain; turning over in bed is sometimes almost impossible. Pain is very commonly referred to one thigh or calf, or both, and it extends at times all the way down to the toes, leaving portions of the leg and thigh painless. There is almost invariably some atrophy of the thigh or calf muscles after a pronounced attack of this trouble. So great at times is this atrophy that it has actually weakened the functional power of the leg, causing in some cases a flat foot. It is commonly found, on examination, that the spinal motions are affected. There is occasionally some list of the trunk to one side or the other. Active motions may be markedly restricted in forward bending and only moderately guarded laterally and backward. The more common restriction is in the lateral motion in the low dorsal and lumbar regions. (Figs. 231 and 232.)

Fig. 231.—Photograph Shows the Restriction in Spinal Motions when the body is bent toward the left side. (Original.)

Usually lateral motion is secured more readily to one side than to the other. In some cases where the degree of lateral motion is not restricted more in one direction than in another, there will be a difference on the two sides in the location of the lesion, as shown by the point where the maximum motion takes place in the two directions. In some cases hyperextension will be the only motion that is at all guarded. There is generally some atrophy of the buttock and the thigh. This is commonly much more perceptible to the touch than to the tape measure. The reflexes are not disturbed. There is no tenderness along the course of the sciatic nerve, and it is not always in the

course of the sciatic distribution that most of the pain is located. Respiratory excursion is not generally interfered with, as it is in the advanced infectious cases. In the cervical region there is apt to be a torticollis, and the pain is referred down the arm to the hand and is accompanied at times by numbness and prickling, and exceptionally by a paresis. In the treatment of this disease in the vertebral column, fixation is what the part is in need of. It is best secured by a plaster jacket applied from the level of the trochanters, on the side and behind, to the bottom of the axillæ. It should be put on while the patient is in the standing position, preferably with a slight degree of lordosis. It commonly gives great relief at once; and if it fails to do so after a few days, when it has been properly applied, suspicion should then be aroused as to the accuracy of the diagnosis. Enlargement of the mesenteric lymph nodes, Pott's disease without deformity, aneurism, and infectious processes in the spine are the principal conditions from which the disease should be differentiated. Fixation will have to be kept up very faithfully for five or six weeks before the patient can give up a plaster or leather jacket. Webbing belts are useful in the convalescent stage. Recurrences are not uncommon.

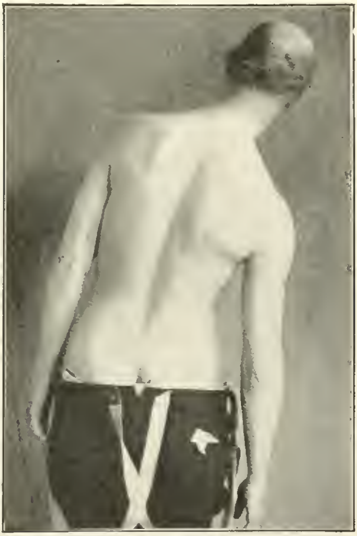

Fig. 232.—Shows the Same Restriction when the body is bent toward the right side. (Original.)

Shoulder.—Lesions of a true hypertrophic arthritis in the shoulder joint are not very common. Periarthritis and inflammation of the subdeltoid bursæ are much more common. These follow upon traumatism, show no hypertrophic lesions in the x-ray picture, and yield to manipulative treatment under an anæsthetic. As to the diagnosis and the treatment in these cases, the surgeon will find that it is a safe rule to be guided by the x-ray picture. When there are bony enlargements or osteophytes in evidence, then manipulation should be avoided and fixation should be pursued.

Elbow.—In the elbow hypertrophic lesions are quite common. The anatomical peculiarities of the joint lend themselves very well to the deposition of these plastic bony deposits, and they very readily interfere with the motion of the joint, both in flexion and in extension. The traumatisms of hard man-

ual occupations, as well as the traumatisms of such sports as tennis, baseball, and polo, tend to the production of such lesions in the elbow. The deposits most commonly occur along the olecranon and the coronoid. (Figs. 234 and 235). They are easily demonstrable in the x-ray picture. Pain in the joint when it is used, with the preservation of a considerable degree of free motion, while at the

Fig. 233.—Shows a Calcification of the Subdeltoid Bursa, evidently representative of the hypertrophic process which was in evidence in other parts of the patient's body. (Original.)

same time the radius of mobility is restricted to a very considerable degree in both flexion and extension, are the chief objective and subjective signs. In treatment the cardinal principle employed should be surgical rest in a removable, fixative apparatus of leather, plaster, or celluloid. In the occupational forms of the hypertrophic lesion, arthrotomy and removal of the spurs from the olecranon and coronoid processes have yielded very good results, both as to the relief of the symptoms and also as to the improvement of function.

Wrist and Fingers.—The carpus is practically exempt from these lesions. To the fingers belongs the distinction of having Heberden first describe this disease in them in the seventeenth century. In this situation the disease attacks the terminal phalanges almost invariably. The x-ray shows the bony deposits very distinctly. They are along the margins of the articular cartilages, (Fig. 236), are not symmetrically placed, and therefore are apt to deflect the terminal phalanx in one direction or the other through the pressure of these nodes. They are more commonly seen in women, and especially women who subject their hands to hard usage in housework, sewing, etc. The formative stage is

Fig. 234.—Shows Lipping of the Lower End of the Humerus, of the olecranon process of the ulna, and, to a slight extent, of the head of the radius. (Original.)

sometimes painful, but more often not. Here, more than in any other joint in the body, these lesions are tender to external pressure. Putting on gloves and such manipulations are painful in these cases. Patients will not as a rule subject themselves to the inconvenience of having fixative treatment applied to these joints, especially as the end results are not very crippling. Baking in hot sand, sweating the affected joints by rubber cots, etc., afford the greatest relief. At the same time the patient should avoid as much as possible the manipulations which cause discomfort to the joints.

In general, the prognosis of this form of arthritis, as regards the ultimate function of the joints, particularly of the smaller articulations, is very good. Pain and disability tend to lessen under any or no treatment, but when such therapeutic measures as have been indicated are employed, the course of the

disease may be shortened and the final functional results be materially improved. The manifestations of the disease, according to Osler, are evidences of longevity.

IV. CHRONIC VILLOUS ARTHRITIS.

This condition has been virtually described in the section on "Infectious Arthritis," but, inasmuch as it is regarded by some observers as an entity, it seems desirable to devote a little more detailed description to it in this place. Schueler was the first to establish its bacteriologic etiology, and shortly afterward Ban-

FIG. 235.—Antero-posterior View of the Same Case. (Original.)

nantyne and Wohlman described an organism which they had succeeded in isolating from joints, and which they claimed was the specific cause of the joint inflammation in question. Their organism was different from Schueler's, but both observers obtained an organism with constant morphological character-

isties in all their cases. In the light of the work which has been done on infectious processes in joints in recent years it would seem that such variability in the characteristics of the bacteriologic findings was exactly what might be expected when one recognizes the fact that many bacteria may be the cause of intra-articular tissue changes very similar to those which are the subject of this discussion. Furthermore, there seems to be no doubt that, even when bacteria themselves cannot be demonstrated either in the fluid of the joint or on examination of the tissues which line the joint, we are justified, from the

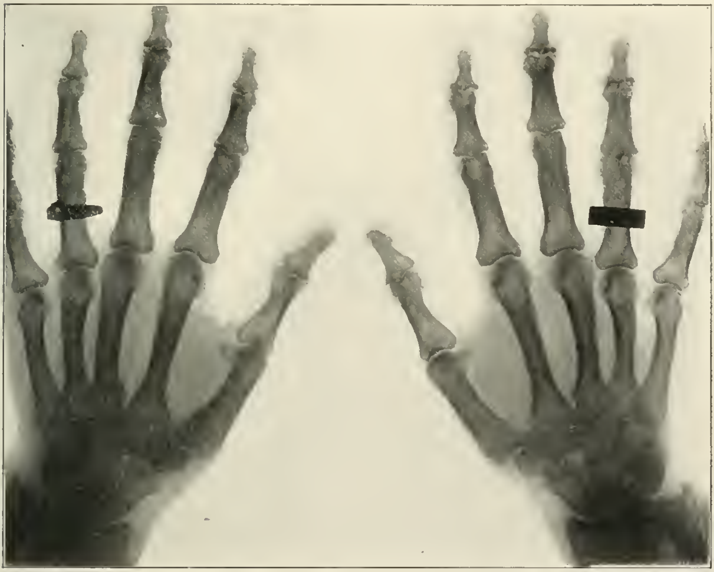

Fig. 236.—Shows the Overgrowth of the Cartilage in the Terminal Phalanges Characteristic of the Formation of Heberden's nodes. (Original.)

character of the tissue changes produced, in inferring the action of some toxins which possibly have been absorbed from a remote focus. That there is any specific bacillus, as claimed by Schueler and Wohlman, for this condition, is a statement which, in view of the later investigations, seems to lack confirmation. In syphilis the writer has seen as pronounced villous changes in the capsule of the joint as were ever observed in any of the more acute infections, and this was in the stage just preceding the disintegration of the knee joint from Charcot's disease. Bacteriologically, no organisms were demonstrable in the tissues. From purely traumatic causes, particularly when the trauma is an internal one, we may get extensive, local, villous changes in the synovial mem-

brane entirely dissociated from any bacterial or toxic cause. These, to be sure, are monarticular, but there seems no good reason for making any other classification for the chronic polyarticular villous changes in joints than the one already made, of "Infectious Arthritis."

V. FOREIGN BODIES IN THE JOINTS.

In certain of the larger joints of the body it is not uncommon to find interference with their function and other disturbances associated with the detachment of cartilages essential to their integrity or hypertrophied osseous nodes so separated that they are free in the articulation or movable through a considerable arc, their radius of motion being determined by the length of the pedicle which attaches them to the side of the joint. The joints in which such conditions are most likely to be found are the joints chiefly concerned in locomotion, as they are more subject to the traumatisms which are capable of detaching nodes or displacing cartilages. The knee joint comes first as the most frequent seat for these troubles; next the hip; then the elbow, the shoulder, and finally the ankle.

Aside from the occasional and accidental introduction into a joint of a foreign body from the outside, the three common causes for "joint mice" are: (1) hypertrophic arthritis or "lipping" of the articular cartilages; (2) traumatic detachment of portions of the articular cartilage, either through direct violence or through muscular pull or torsion, (3) the formation, in the synovial membrane, of small pedunculated tumors through a metaplasia of tissue. These occur presumably in some villus which has become hypertrophied because of pre-existing joint inflammations, or, in the absence of such inflammations, there may be congenital causes, bone and cartilage cells having been included in the synovial membrane in the same way that we find other kinds of cells widely separated from their proper situation. It seems probable that, inasmuch as it has been repeatedly demonstrated that various organisms may be found deeply seated in the subsynovial tissues of inflamed villi, their presence there may, under certain circumstances, set up a metaplasia causing the ordinary synovial tissues to revert to cartilage or bone. Sometimes no metaplasia occurs, but a great increase in fibrous tissue only, as though some irritant were being encapsulated in order to protect the rest of the joint from invasion. The writer has seen one large pedunculated tumor of this sort in the knee joint. It had its attachment by a small pedicle to the external tibial condyle. It was about the size of a pullet's egg and was made up of a series of lamellated layers of fibrous tissue about what seemed to the pathologist to be an aggregation of tubercles. The patient, a young woman, was employed in a factory where she ran a machine, in the management of which she was obliged to throw the power

off and on repeatedly by means of a lever which she pressed with the outer side of her knee. The subsequent development of other lesions showed that this tumor was syphilitic in character, and treatment along those lines effected a cure of the other lesions, as it doubtless would that of the knee had not surgery been resorted to to remove the growth on the supposition that it was tuberculous.

I recall an instance of a larger tumor that occurred in the knee joint of a young man who evidently had an infectious polyarthritis. In this case there was some villous change in the joint capsule. No organisms were demonstrable in the tissue of this case and none in the fluid obtained from the joint. The fibrous tumor had a very slender pedicle, which was attached to the internal alar ligament and allowed the tumor a considerable excursion within the joint. Pedunculated bodies in the joints are not often encountered, but it is quite possible that many of the loose "joint mice" may have been pedunculated at some time in their history and that the pedicle had been twisted off, thus setting the tumor free. It is very difficult to find the scars that indicate the points where these "mice" were attached, it being assumed that they must have been chipped off from some portion of the articular cartilage. In cases where there are several "mice" in the same joint it is very probable that they represent detached "lips" of hypertrophic origin. They are of considerable size and show facets, as gall stones do, where they have rubbed over one another. Lipping can hardly occur to a sufficient degree to permit of such extensive osteophytic formation in any other joint than the knee.

Treatment.—For the relief of the definitely formed "joint mouse" in a young person in whom the symptoms of "locking" or "catching," succeeded by a slight or considerable effusion, are repeating themselves frequently, there is very little use in the practice of conservatism. The body can usually be found at any time by a little manipulation, and it is generally possible to remove it through a small opening in the joint and without passing any thing within this opening except the point of the instrument. Under such circumstances the risk of infection is almost nil. In elderly persons with hypertrophic arthritis the detached "lips" in the knee can frequently be so controlled by adhesive strapping that these patients can be kept very comfortable, and by persistence in this plan of treatment it may be possible to secure the pocketing of the osteophyte in such a way that the treatment may eventually be omitted.

In extreme cases where there are many osteophytes in the same knee, locomotion is extremely painful, if not almost impossible. Motion may be reduced to practically nothing, and a small amount of deformity in the direction of flexion is quite certain to be present. In such cases, even in persons fairly advanced in years, the removal of the osteophytes is justifiable after conservative attempts to hold the "joint mice" in places where they can do no harm have failed; for, although motion will not probably be secured, the pain

of locomotion will be lessened and greater comfort and activity will be given to declining years.

In the elbow, although hypertrophic lesions and infectious processes are common enough, we seldom find "joint mice." This is probably to be explained by the fact that the elbow joint is better protected from traumatism than is the knee. Recently the writer has had under his care the only case of foreign body in the elbow joint which he has ever seen. The essential facts are stated in the following brief account:

The patient, a young man of thirty-five years, had for fifteen years been occasionally made aware of the fact that there was something wrong with the left elbow. When he was about twenty he injured this joint, and for some time there was impairment of function. Five weeks before visiting the clinic he had been wrestling, and something slipped in the elbow joint, causing him a great deal of pain and preventing, under certain conditions, the extension of the forearm. On feeling the back of the joint he could at times find a small, tender, movable body. At the time when he visited the clinic this body was easily distinguishable just behind the internal condyle, and it could be slipped about within a short radius. At the operation it was found that the tumor did not seem to possess a definite pedicle; it was a very hard piece of eburnated cartilage, which doubtless was originally chipped off from the edge of the internal trochlear surface of the humerus. Perfect function of the elbow was secured two weeks after the operation.

The shoulder joint rarely has foreign bodies loose in it. The shallowness of the glenoid and the lack of any very abrupt shading off of the head of the humerus into the neck of that bone do not offer much of a surface upon which lipping may occur. The capsule of the joint, like that of the hip, is closely apposed to the bone, and villous changes as a result of inflammatory processes in the joint do not occur to anything like the extent that they do in joints of other types. These facts afford a possible explanation of the infrequent occurrence of detached osteophytes within this articulation.

If surgery were needed in these cases, no more accessible joint could be found to practise it upon than the shoulder joint.

So far as the ankle joint is concerned, the writer has seen only one case in which a "joint mouse" was present in that joint. The foreign body consisted of a fibrous growth which was situated just to the outer side of the median plane of the ankle joint and just below the level of the line of the articulation between the tibia and the astragalus. Its size was about that of a lima bean; it was shortly pedunculated and could be slipped about. Two years before I saw her the patient had pneumonia and, following that, she had a pneumococcic polyarthritis involving both ankles, wrists, shoulders, back, and the sacro-iliac articulations. In view of the facts that considerable diffuse capsular thickening of the ankle joint remained after the subsidence of the arthritis and that the "mouse" was embedded in the midst of this villous capsular thickening,

it seems probable that in this case we were dealing with such a tissue change as has been already described as one of the possible causes of foreign bodies in the joints.

VI. JOINT FRINGES.

Under this heading it is desired to treat only of the mechanical effects of hypertrophy in the normal fringes of the joints. Under Infectious, Atrophic, and Villous Arthritis some consideration has been given to the etiologic factors which are concerned in the production of fringes. But under those headings only examples of the acute stages were regarded, and, furthermore, all the causes for joint fringes were not carefully examined. It is necessary to bear in mind that a joint fringe is a normal component of all articulations. It is only in virtue of its existence that the synovial membrane can accommodate itself to the widely different positions of the component bones of the articulation which are made necessary by flexion and extension. They are not normally visible to the unaided eye, but show quite plainly on histological examination. The alar ligaments, which are two wing-like folds of tissue on either side of the patellar tendon and in a plane slightly posterior to it, are covered with synovial membrane, and seem to have for their function the lubrication of the joint as they brush over the surface of the femoral condyles in the act of flexing and extending the leg. Their situation is such that they are liable to many traumatisms from the interior of the joint. The ligamentum mucosum forms a part of the support to the alar ligament, and my attention has been called to the fact that, in dissecting-room subjects, these ligamenta mucosa have in several instances been found to be ruptured. This allows the alar ligament to sag farther down into the joint than normal, and when this happens the tip of the alar ligament is very likely to become pinched; if this occurs with sufficient frequency the tissue becomes hypertrophied and a pathological joint fringe is formed. This rupture of the ligamentum mucosum cannot be diagnosed, but it is probable that some of the twists and wrenches to which the knee joint is liable result in tears of these ligaments, often associated with acute symptoms and eventually followed by fringe formation.

Under many conditions the body loses its tone, and this is true particularly of the muscles. Because of their insertion into the ligaments and fasciæ everywhere, the muscles play a very important part in the support of the joint capsules. Conspicuous among the factors which induce loss in muscle tone is nervous prostration. Joint fringes in the knees of sufferers from this condition are not uncommon. Acute diseases have a somewhat similar effect, causing a decided loss in vigor of the entire musculature, and even without any possible infection of the synovial membrane we shall find that the development of the alar folds has gone on to an abnormal degree. The traumatism of a partially

detached semilunar cartilage frequently irritates the normal folds of the synovial membrane within its reach to such an extent that it is sometimes difficult to distinguish between the symptoms which are due to the displaced cartilage and those which are attributable to the pinching of a synovial fringe. Relaxation of the joint capsule to such a degree as to permit of an habitual luxation of the patella is almost invariably associated with hypertrophy of synovial fringes.

One case of varix of the synovial membrane has come under the writer's observation. As a result of the great increase in the blood supply of that portion of the synovial membrane in which the varix was situated, it had become much thickened and interfered with the normal motion of the joint. This occurred in the knee joint. The synovial thickenings, which are the result of either lipomatous infiltration or degeneration, will be discussed separately. Static disturbances in the feet and ankles are a frequent cause of the disarrangement of the mechanics of the knee. Valgus, with its accompanying abduction of the front part of the foot, causes the weight to be borne abnormally upon the tibial and femoral condyles. This means that the line of weight-bearing is shifted in such a way that, instead of passing through the centre of the long axis of the foot, it falls to the inside of this. More strain is brought in this position upon the internal lateral ligaments of the knee, and in these cases the symptoms of hypertrophied joint fringes are common. Direct violence from the outside not infrequently causes an hypertrophy of the synovial villi, and characteristic symptoms arise.

The physical sign of most constant occurrence and of greatest clinical significance is swelling of the joint, usually very definitely localized on either side of the patella tendon just opposite the line of the articulation. As a rule, this swelling is about equal on the two sides of the tendon. It is noticeable to the eye through its disturbance of the contour of the joint, and the condition is also revealed by the tape measure through comparison with the unaffected side. Rarely is there any general capsular infiltration or any excess of fluid within the joint. Motion is not usually restricted in any way, although sometimes there may be some interference with extreme flexion or extreme extension; the latter being more frequently restricted than the former, probably because the hypertrophied alar ligaments drop in between the tibia and femur and block extension. In some cases complete extension is not possible, either actively or passively; in others the entire amount may be obtained, but only at the expense of a good deal of pain. There is no locking of the joint such as is seen in displacements of the semilunar cartilage, but there is sometimes a temporary "catch" or a sensation as if the joint were going to "buckle," causing the patient to fall. There is no increase in the surface temperature, and the occasional "catches" are not associated with any increase of the fluid in the joint.

On palpation, the alar-ligament fringes can easily be felt. They are not tender to pressure, and in the larger ones pressure over the enlargement on one side of the patella tendon can be transmitted through to the other side, causing the patella itself to be moved from side to side, in much the same manner as fluctuation would be obtained.

Subjectively, the patients complain of ache and pain referred to the front of the joint just behind the patella, with perhaps a trifle greater frequency upon the inner side of the joint. Occasionally the cords behind the knee are the seat of pain and discomfort. Crepitation within the joint, sufficient to be heard as well as felt in some cases, is a very constant symptom, and is produced by the rubbing of the hypertrophied synovial folds over each other. A perfectly analogous sound, as well as feeling, can be produced by friction of the two surfaces of a rubber "bath mit" over each other. Stiffness on rising after prolonged rest, temporary locking of the joint as distinguished from permanent locking, and, in the absence of this, the weak feeling which is common to these joints, are the most usual subjective symptoms.

In *treatment*, correction of any static defects must be secured, either through a "Thomas heel"* or by means of a properly fitting foot-plate. Adhesive strapping over the front of the joint will give a sense of security in walking, will relieve some of the pain and discomfort, and may cause the resorption of enough of the hypertrophied fringes to insure their not being pinched in the use of the limb.

Arthrotomy for the removal of these enlargements is sometimes necessary and yields good results, provided early manipulation of the joint is performed. After the stitches are removed from the operative wound, passive manipulation should be undertaken, and usually at the end of the second week right-angled flexion, or a little more, may be secured. Customary function, after this amount of motion has been secured, readily follows from routine use.

Showering the knee in hot and cold water alternately applied, and supporting it with a flannel bandage during the first two or three weeks after the arthrotomy, will favor restitution to the normal condition. Where the fringe formation is due to such internal derangements of the knee joint as displaced semilunar cartilages or habitual dislocation of the patella, these must be corrected at the time when the fringe is removed.

* This consists of a wedge-shaped leather list inserted in the inner side of the heel of the shoe, making the inner edge of the heel from one-eighth to one-quarter inch higher than the outer side.

VII. SYPHILIS.

The joint lesions of syphilis are of more frequent occurrence than some writers or most text-books would lead us to suppose, but they are, on the other hand, not so common as some would try to persuade us—men who see syphilis at the bottom of all of the so-called rheumatic affections, and who believe that it complicates many of the tuberculous lesions. It certainly is a hard problem to solve, and, in spite of the many refinements of diagnosis which have come into vogue in the last few years, the fact remains that there are still insurmountable difficulties in diagnosing the joint manifestations of syphilis. That attitude of mind which discounts in every case positive statements on the part of patients when they deny having had venereal disease, either syphilis or gonorrhœa, and assumes that they must have had one or the other as the case may be, because otherwise they (the physicians) would not be able to attach a name to the particular form of arthritis from which the patient is suffering, is not conducive to clear reasoning and does not bespeak a capacity for the weighing of evidence. The patients who will lie about themselves in this particular are much fewer in number than the physicians who are willing to assume such a cause for an arthritis which they have neither the ability nor the industry to fathom. Some physicians fail to pay a proper respect to history-taking in attempting to solve problems of this kind. Direct questions pertaining to syphilitic infection in the subject under examination are embarrassing to put, and, even when such questions are put and answered negatively, the assumption of evasion or positive falsification is an easy and common assumption to adopt. Oftentimes the occurrence of syphilis in the immediate ancestry of the patient in question may be overlooked, and thus important etiologic evidence be missed.

Syphilitic bone disease, when it occurs away from the articulations, will not be discussed in this article. (*Vide* the article on this subject in an earlier part of this volume.) Only such lesions as are seen in the synovial membrane of the bones composing a joint, within the boundaries of that joint, will be discussed here, together with the form of syphilitic joint lesion which is familiar under the name of *Charcot's joint.*

Syphilis shows itself in the synovial membrane as a gummatous infiltration or as a diffuse villous arthritis with no very special histologic characteristics. So closely indeed may the histologic signs of syphilis in the synovial membrane resemble those of tuberculosis that even expert pathologists may fall into error in reference to this question. A case in point is well remembered by the writer:

A young woman, about twenty years of age and of unimpeachable character, was seen about six years ago. She was employed in a shop where it was her duty to run a machine which obliged her repeatedly to throw the power off or on. This was accomplished by crowding the outer side of the right knee against the

iron "cut-off" of the machine. The knee was somewhat swollen and there was some synovitis. The greatest swelling was over the outer side of the joint just beneath where the treadle of the machine caused its irritation.

An exploratory operation was advised, and the growth was removed. it was found to be, according to the pathologist's report, tuberculous. On the strength of this report the knee was excised. Convalescence from the excision was uneventful, but, during the ten or twelve weeks which succeeded the excision, sluggish ulcerations appeared on the left chest and extended up over the neck. These had undermined edges, were very indolent, and showed no tendency to heal under any local treatment. Potassium iodide was administered in liberal dosage, with the result that the ulcerations very promptly closed in and the entire area healed within three weeks. This quite conclusively showed that the original trouble was syphilitic in nature. Further confirmation of this opinion was soon to come, as there appeared, in the upper part of the left humerus, a swelling which was annular in its distribution and occupied the entire cortical portion of the bone, as was shown by the *x*-ray. Under the administration of potassium iodide internally and inunctions of mercury this underwent much diminution in size, and, although at the present time it has not entirely disappeared, it is causing her no trouble. During the three or four years which have elapsed since the operation it has been necessary for her to keep up the iodide the greater part of the time, as relapses of her syphilitic infection have occurred, and only under increased dosage and a resumption of full antisyphilitic treatment have these symptoms been made to disappear.

It would seem, from a consideration of this case and from the experience of other surgeons as well, that the differentiation between syphilis and tuberculosis, even when opportunity is offered for histological study, is at times a difficult one to make. It is for this reason that clinicians have preferred to err on the side of administering potassium iodide to the tuberculous patient rather than to take the responsibility of according surgical treatment to a lesion which apparently required it, but which was syphilitic in origin. The reasons for this fear are, of course, obvious. The knowledge of the use of potassium iodide is widely diffused now, even among the laity, and the giving of a prescription in which this drug is ordered, to a patient who had not syphilis, might lead to considerable embarrassment. These facts should lead us to be more careful in our search for reliable signs which will enable us to distinguish between these two diseases without recourse to the therapeutic test, and it is the writer's belief that in the majority of instances we do have at our command resources in diagnosis which will enable us to discriminate between these conditions in the vast majority of cases.

Syphilitic joint lesions manifest themselves either in the bones composing the joint or in the synovial membrane which encloses it. Sometimes the osseous lesion is in the epiphysis and breaks through into the joint; sometimes it is in the diaphysis and breaks through the epiphyseal line, and, without actually invading the joint itself, gives rise to symptoms which are suggestive of an actual involvement of the articulation. The juxta-epiphyseal lesions are

very well illustrated in the accompanying x-ray picture (Fig. 237). The larger number of osseous lesions which occur are of this character. They are quite as abundant as the periosteal and cortical lesions in the middle of the shafts of the long bones.

Gummatous deposits in the synovial membrane are more rare than the osseous lesions, but they do occur. Inasmuch as they rarely suppurate, and thus do not have the capacity for eroding their way rapidly through tissue, they may cause a very considerable infiltration in the synovial membrane where they are situated without causing any disturbance in the neighboring articulation. This is one of the characteristic features of the synovial syphilitic lesions, whether they be gummatous or consist of a diffuse infiltration of the entire synovial layer. Except for the swelling which they undergo, and the occa-

Fig. 237.—Shows on Both the Tibia and the Femur the Extreme Epiphyseal Rarefaction which is characteristic of the juxta-epiphyseal syphilitic disease. (Original.)

sional mechanical interference with the function of the articulation, they are quite apt to go unrecognized or to be regarded in such a trivial light by the patient that no advice is sought until the lesion is well advanced.

A typical case of this sort is worth recording, if only to emphasize the type:

A young man of twenty-eight presented himself because of a swelling of the right knee. This had been of gradual development, was not associated with much, if any, discomfort, and had interfered only in a very slight degree with the function of the joint. He was employed in a railway watch-tower, and it was necessary for him to put a rather severe strain upon his joints, but he was able to do his work and did not have to give it up at all on account of his disability. The knee was very large; the joint capsule seemed symmetrically infiltrated throughout its entire extent; and the induration was very thick, there being practically no excess of fluid in the joint. The joint motions were not restricted, except that flexion could not be carried to quite the extent on the affected side that it could

on the well side, and this was apparently because of a mechanical obstacle to extreme flexion. There was no increase of the surface temperature; there was no tenderness to pressure; and use of the joint was practically painless. There was no tendency to permanent flexion or other deformity in the knee joint. The general condition was not very good. The young man was rather anæmic, but his occupation confined him so closely that it seemed no more than reasonable to suppose that this was competent to account for his anæmic appearance.

The arthritic condition was regarded at the time as a chronic rheumatoid process, and an operation was advised for the removal of the obvious synovial

Fig. 238.—Illustrates a Gummatous Condition of the Patella, that bone having undergone partial disintegration. Condition cleared up under antisyphilitic treatment. (Original.)

fringes. These were accordingly excised through lateral incisions, and the entire synovial membrane was found to be markedly infiltrated. The villi were very conspicuously enlarged, velvety in appearance, and afforded a considerable obstruction to the free use of the joint. These were dissected out thoroughly, the joint was closed without drainage, and at the end of two weeks passive motion was commenced; as a result, complete restitution of the joint to its passive function was speedily accomplished. The patient's general condition was somewhat improved by the necessary abstinence from work and by reason of his living in better hygienic surroundings; and the removal of this amount of villous material

from the articulation was doubtless of benefit to the joint, and also indirectly to his general condition. He returned to work and remained at his customary occupation during the year and a half succeeding the arthrotomy. At the end of that period the joint began to swell again, this time below the line of the articulation, and the swelling was confined principally to the region immediately below the patella. (Fig. 238.) He did not consult with any one in reference to this swelling until an ulceration appeared directly below the patella, close to where the patellar tendon is attached to the bone. This was a sluggish, indolent ulcer, with undermined edges, ragged in appearance, and with a rather dirty base. The *x*-ray showed considerable thickening and infiltration of the patella itself and of the soft parts in the neighborhood. Because of the suspicious appearance of the ulcer and its clinical course it seemed probable that the lesion was syphilitic. He was put upon inunctions of mercury, and potassium iodide was administered by the mouth, with the result that the ulcerations on the front of the knee very promptly healed. The infiltration of that portion of the synovial membrane which had become involved at the second observation disappeared, and the patient, while kept under the influence of these drugs, has remained entirely well. His general condition improved coincidently with getting his syphilitic infection under therapeutic control.

Fig. 239.—Case of Syphilitic Disease of the Knee Joint. The photograph shows the typical swelling of the knee with hyperextension very well demonstrated in the lateral view. (Original.)

A similar pathological condition has been seen by the writer in the case of a young man who had an unquestioned history of syphilis, and in whom, since the first observation, Charcot's lesions have manifested themselves in one knee joint:

This patient presented himself for treatment after having had a swelling of one knee of a chronic character, but which had apparently been induced by a severe strain that had been imposed upon the joint. (Figs. 239–242.) The synovial membrane

was greatly thickened; there was very little excess of fluid in the joint; the patient's general condition was excellent. He was having some pain in the knee, but no more than it seemed would be natural with the amount of swelling which was there present. There was a slight amount of permanent flexion, but otherwise the motions of the articulations were good. There was a slight increase in the surface temperature. The *x*-ray showed absolutely no change in the contour of the osseous elements of the joint, but did show an extensive infiltration of the synovial membrane. The patient's reflexes were tested and it was found that he had no sign of the infection of his central nervous system by syphilis. An arthrotomy was done and a condition was found within the joint very similar to that which has been related in the last case. Histologically, it was impossible to make any other diagnosis than that of a chronic inflammatory process, non-tuberculous in character. There was nothing peculiar with reference to his convalescence from the operation except that, through the opening which had been left for a provisional suture, and in which a wick was allowed to remain for forty-eight hours, a very large amount of serum was discharged almost constantly for upward of four weeks. The flow then gradually slackened and finally ceased altogether. When it had entirely ceased—*i.e.*, about six weeks after the operation—there was a considerable recurrence of the synovial infiltration of the joint. More than that, there was detected an abnormal mobility which steadily increased, so that, the last time he was under observation, the joint could be bent up into a hyperextended position through an angle of fully forty-five degrees. There was also a considerable degree of lateral play, even with the leg in an extended position. Within the joint there could be felt several irregularly shaped masses which evidently represented parts of the femoral and tibial condyles which had been separated and were wholly or partially free in the joint cavity. There was no muscular spasm in the joint and the motion of it was entirely painless, even when carried through the extremes of hyperextension.

Fig. 240.—Front View of the Same Case (see Fig. 239). (Original.)

In this case, then, we have evidence of a diffuse syphilitic involvement of the synovial membrane in the pre-Charcot state, a process which we have seen in other cases where there was no involvement of the central nervous system with syphilis. It is probable that the syphilitic virus or toxin was capable of inducing a villous arthritis in the same way that any toxin is capable of inducing a villous change in the synovial membrane when it has access to the joint; and such facts should emphasize the necessity for careful search for

Fig. 241.—Syphilitic Lesions of the Knee Joint. In the radiograph the destruction in the cartilage and the absorption of the trochlear surfaces are very well shown. (Original.)

evidences of central-nervous-system involvement in cases of monarticular arthritis of the villous type. It may be that more of these cases are syphilitic than we now believe, and that a certain number of them may have concomitant cord lesions that are due to the same infection and that are sufficiently far advanced to be detectable upon careful observation.

If such conditions could be recognized, operative surgery would of course not be undertaken, as doubtless the internal administration of potassium iodide and inunctions of mercury would have caused the villous change in this articulation to have disappeared quite as readily as did the knife, and more perma-

nently. As our knowledge of the various possible manifestations of syphilis enlarges, we should hold ourselves in readiness to recognize it as the possible cause for joint lesions in a certain number of cases. We should, however, be cautious in jumping at the conclusion that syphilis is present when it is not. The usual points in establishing a syphilitic diagnosis are, of course, to be sought for in the personal or family history of the patient. The ordinary signs which are looked for as evidence of the presence of syphilis should be invariably sought, viz., loss of hair, presence of Hutchinson's teeth, repeated sore throats, stoma-

Fig. 242.—Radiograph of Both Knee Joints. The same case as that shown in Fig. 235. (Original.)

titis, the characteristic scar formations about the alæ nasi and the corners of the mouth, the presence of corneal ulcerations, and the presence of osseous nodes, although these are rather rare. We should discourage the use of anti-syphilitic remedies for diagnostic purposes, both from the fact above mentioned, that they may cause embarrassment to the patient, and also because the employment of such measures tends to make one lax in physical diagnosis.

The *treatment* of syphilitic joint lesions is practically solved when once the diagnosis is made. The dogma of Dr. Henry J. Bigelow that the "great object of surgery is the avoidance of operations" will be fulfilled, certainly in syphilitic cases, when we have perfected our diagnosis sufficiently to enable us to recognize the joint lesions as they present themselves.

Broken-down gummata should, of course, be opened. That type of joint syphilis which is recognized under the name of Charcot's disease is occasionally subjected to operation, but usually with but little benefit. Excision of joints which are subject to this form of joint derangement is generally attended with non-union, and, of course, the removal of the articular surfaces from such joints can have nothing to do with the cure of the disease. That must be accomplished through therapeutic measures, and, happily in the great majority of cases, when this is judiciously planned and faithfully carried out, it will be found that this disease is more amenable to thorough curative measures than any infectious disease which we know. In certain cases some assistance can be rendered by means of apparatus. Jointed knee splints of the pattern which is used for the bad cases of infantile paralysis are of service in preventing the hypermobility which the Charcot's knee joints show. Also in the cases of the destruction of the femoral head by this process, splints which are constructed on the principle of the spica or on the principle of the crutch will be found to be of value in controlling the abnormal motions of the hip joint. These two articulations are the ones which are most seriously handicapped by the manifestations of spinal syphilis, and consequently are the ones which receive most benefit from treatment.

The *prognosis* of syphilitic joint lesions is good in proportion to the earliness of their recognition, and varies, of course, considerably according to the part of the articulation which is affected. The gummatous and the diffuse infiltrations of the synovial membrane when properly treated are very amenable to antisyphilitic therapeutics. The same is also true of the gummatous involvements of the bones. To a lesser degree is this true of the juxta-epiphyseal osseous foci. The prognosis in the Charcot's joints, where the disease has involved the spinal centres, is, of course, extremely bad.

VIII. FUNCTIONAL JOINT DISEASE.

One of the most difficult of all conditions to be met in the treatment of joint disease, as well as in the diagnosis of the same, is that in which the symptoms have no basis in demonstrable organic disturbances. It is hard, when one is confident of being right in the diagnosis of functional conditions, not to be indifferent in the matter of treatment, forgetting that what we know to be imaginary in a considerable degree has a very definite basis in the mind of the patient, and that the treatment must consist in expelling from the patient's consciousness the vicious train of thought which has led up to his condition.

Many cases of organic joint disease have added to the joint trouble itself an element of functional or neurasthenic taint which it is almost impossible for the patient not to acquire in fighting a chronic, progressive joint disease through

a long course. To this class of troubles belong the so-called neurasthenic, hysterical, neuromimetic, or functional disturbances, which have been referred to above.

Young and impressionable persons are the ones who are most liable to this sort of trouble, and it is in them that it is most difficult to make the diagnosis, although in them, happily, treatment is more readily responded to than in those of more mature years.

The joints in which symptoms of this character are most likely to be manifested are the spine, the hip, and the ankle. Women are more liable to disturbances of this sort than are men.

The development of symptoms is associated with nervous prostration, overwork, be it mental or physical, shock, such as is sustained by those who are the victims of accidents, whether there be much physical injury or not; and, in certain cases, the element of mimicry of symptoms existing in those with whom a patient similarly affected has been closely associated.

The evidences of a condition of the nervous system which would permit of the development of joint symptoms in these patients, are generally easy to find, if close attention is paid to history-taking. It is oftentimes very hard, without such evidence, to make a diagnosis, so perfect at times is the simulation of the symptoms that belong to an organic lesion. Of these symptoms there are certain ones which belong in common to all joints; that is, they may manifest themselves in the case of any joint in the body. The most conspicuous of these is the disproportion existing between the subjective and the objective signs.

In the *spine*, where, perhaps, the largest number of non-organic lesions occur, deformity is generally lacking, certainly any deformity which would indicate the existence of some destructive change or of some deformity in the vertebræ themselves. In other words, there is no kyphosis or rotation. There may be a total deviation of the column laterally from the perpendicular, or there may be a rounded kyphosis, involving the whole column, or a combination of both. Such deformities will be voluntarily correctable on the part of the patient in some cases, but in the majority of cases it will be necessary to resort to forceful, passive over-correction, or to keep the patient for a considerable period of time in the recumbent position. The normal physiological curves of the spine are generally obliterated. In most cases, the lumbar lordosis is almost wholly wiped out, and there is an exaggerated rounding of the cervico-dorsal curve. In other cases there will be found a very much exaggerated lordosis.

Active and passive spinal motions are present, as a rule, though possibly somewhat guarded by a voluntary muscular spasm, which it is not hard to distinguish from true muscular spasm of involuntary character. The patients usually have a very flabby musculature; almost invariably is this so in

women, and they are quite often rather anæmic. Hyperæsthesia of the skin is very characteristic of these patients. The slightest pressure of the hand over the skin of the back evokes a great deal of apparent discomfort. Firm, sustained pressure seems much more tolerable than when it is light and transitory. Certain regions of the spine seem more easily and constantly affected in this way than others, though the entire column is occasionally involved. The region between the shoulder blades is, perhaps, the most constantly concerned.

It is not an unusual thing to find, associated with these troubles, evidence of ptosis of various internal viscera. Gastroptosis, enteroptosis, floating kidneys, as well as the various pelvic disorders of women which are dependent upon relaxation of the sustaining ligaments of the pelvic viscera, are quite frequently demonstrable with spinal symptoms, and treatment which corrects one, provided it is based upon an endeavor to supply the lacking muscle and ligamentous tone, will effect a cure in the other.

In the more profound cases, various other hysterical stigmata may be found. Sleeplessness, anorexia, polyuria and constipation are very constantly present, and altogether these patients present a pitiable appearance.

As regards *treatment*, the milder cases generally respond at once to gymnastic exercises. These should be carefully graduated to the patient's strength, and increased from week to week until the muscular tone is restored to a normal state. A light back brace is occasionally necessary, to act as a reminder to those patients to keep themselves erect and not to assume faulty attitudes in sitting or standing.

In the more severe cases the problem of treatment is a more difficult one. Fixation in a plaster jacket, though it may seem irrational in a patient who complains that the pressure of the clothing is intolerable, yields the most immediate rest to the irritated spinal nerves and muscles, and doubtless produces some effect through suggestion. As soon as may be, this should be split, permitting of certain passive exercises of the spinal muscles, combined with massage, either manual or mechanical, and hydrotherapy. As improvement is noted, less and less mechanical support should be afforded, more and more active spinal exercises should be performed, and there should be blocked out a regular day's order of exercises, representing a steady, though slow, progression from day to day; and from this régime no deviation should be permitted except under very unusual circumstances, and then only with the consent of the physician in charge.

It is very essential that the management of the patient should be centred in one person, who assumes toward her the attitude of a dictator. General tonic treatment will be of assistance.

These profound cases rarely get back to a wholly normal condition, though great and lasting improvement is possible.

The *hip joint* is quite frequently the seat of simulated and hysterical conditions, particularly in young adults. The points which seem to differentiate this condition from organic lesions are of the same order as those which enable one to make the differentiation in other regions. The preponderance of subjective over objective signs gives the best clue to the situation. The patient may hold the joint quite rigidly by a voluntary spasm of the muscles, but there will be no shortening and no atrophy commensurate with the amount of apparent muscle spasm. It will oftentimes be possible to obtain motion in certain directions, when the patient's attention is for the moment concentrated upon something outside of herself or himself, but it will scarcely be possible to do this when the attention is not so distracted. Anæsthetization will render it possible to make the differentiation when other methods have failed, as the spasm which is counterfeit cannot be assumed under ether.

IX. REFLEX JOINT ATROPHY.

This term, indefinite though it is as to the pathology or etiology of the condition under consideration, represents a class of joint lesions which are of considerable importance, if of rare occurrence. They are probably best represented by the bone rarefaction and atrophy seen in the *x*-ray pictures of hands and wrists after fracture of the lower forearm. The carpus frequently shows such an extraordinary degree of this atrophy that the bones seem fused together, almost as if some disease had located there and was producing changes in the bone. Common as this is after fracture, particularly in the situation above noted, it is this condition in the larger articulations, and independent of any fracture, that I wish to emphasize.

Traumatism inflicted directly upon the affected joint, or over the tendons connected with it, is the most frequent cause of the symptoms referred to. The knee joint, because of its exposed position, is more often involved than any other of the large articulations. In this case, the blow or fall commonly brings the force of the trauma upon the patellar tendon immediately over the front of the joint. The immediate, local injury may be so slight as to leave no sign of its existence, and, except for some temporary discomfort, very little may be thought of the injury until some time after its occurrence. Patients then begin to notice that the knee tires easily, and will permit of very much less use than formerly. Pain in the joint is not commonly very severe, and the discomfort which is present is an intolerance of remaining in one position for any considerable period of time.

Atrophy of the muscles in the neighborhood of the joint comes on early and is extensive. The trauma which has caused the atrophy sometimes causes also an hypertrophy of the alar ligaments, so that there will be noted on

either side of the patellar tendon a fulness representing the enlargement of these folds.

Rarely is there any restriction in the motions of the knee joint. Occasionally motion will be guarded by the patient and very frequently complete extension will be prohibited. Other than the possible hypertrophy of the alar ligaments, there is no capsular thickening, and fluid does not accumulate to excess in the joint. Superficial tenderness, and increase in the surface temperature, are, as a rule, absent.

An atrophy of the thigh and calf muscles of from three to six or even eight centimetres is not uncommon. The knee reflex on the afflicted side is generally obliterated, wholly or nearly so. The power in the flexors and extensors of the leg does not seem to be impaired. In the *x*-ray picture no changes are manifest in the soft parts of the afflicted joints, and there is no thickening or erosion of the cartilage between the bones, but the bones themselves show a very marked thinning of their substance, and this rarefaction is sharply localized in the immediate neighborhood of the joint. This is so great, at times, that very little shadow is cast. It would seem as if there were some nervous mechanism having the power to inhibit the growth of bone, or rather the deposit of lime salts in bone, and that this mechanism operates in a reflex manner, through the great tendons connected with these articulations.

The abatement of the joint reflex in these cases would seem to indicate that, whatever the mechanism may be, it is located in the tendons, and that, through injuries to them, some stimulus is transmitted to the reflex centres, which in their turn inhibit the distribution of lime salts.

The whole problem is a complicated one, and not well understood. The practical bearing of it is in relation to questions of diagnosis and prognosis. The tendency is to regard these affections as joint diseases, and to accord them fixation treatment, which is, as a rule, the worst thing that could be done to them, at least if it is to be continued for any considerable length of time.

Treatment.—As the symptoms do not immediately succeed the injury, some time often elapses before the patient seeks advice for anything except the local trauma. Occasionally it is necessary to apply a fixation splint for a short time, in order to control painful symptoms, but this should be so planned that it may be removed daily, and local measures adopted to improve the muscle tone and prevent the relaxation of the joint, which is almost sure to develop to a considerable degree.

After the initial, painful stage is passed, there is not commonly much discomfort in the joint, except the fatigue which follows even slight exercise. Treatment should now be directed toward improving the local circulation by hydrotherapy, massage, and mechanical vibration. Passive motion should be practised daily, to insure the mobility of the joint, and an early return to active functional use should be encouraged. As pain ceases and function returns,

rigid fixation should be given up, and a light flannel bandage should be substituted. Atrophy will persist for a long time, but the ultimate functional results are good.

X. GOUTY AFFECTIONS OF JOINTS.

Gout is a constitutional disease which has joint manifestations. In fact, the latter constitute the chief reason why gouty sufferers seek relief, and yet the treatment of the joint symptoms through local measures does very little to alleviate the discomfort of gouty arthritis.

In considering this subject, therefore, in an article on acute and chronic diseases of the joints, the object in view will be to call attention to such features of the disease as are of diagnostic value in assisting one to separate this form of arthritis from other chronic or subacute arthritides and to help clear up the confusion that still exists in the minds of many regarding the relationship of these various conditions to each other.

In America and among Americans, gout, at least in its more marked forms, is a comparatively rare disease. The few cases, however, that the writer has observed have been in native-born Americans or Irishmen born in this country. Men have, with one or two exceptions, been the victims, and station in life or habits in food or drink seem to have had no causal relation to the development of symptoms. In all cases under the writer's observation, with but one exception, the patients have been from the laboring and middle classes.

Etiology.—Heredity has played no conspicuous part in the etiology. A history of "rheumatism" in the ancestry was frequently obtained, but that this was true gout it was impossible to say, so frequently do we get from patients a history of rheumatism and so many are the types of arthritis to which the term "rheumatism" may be applied. Indeed, it is very questionable how frequently one is justified in accepting the statements of a patient who seems to place the responsibility for his gouty arthritis upon his ancestry. From the carelessness in nomenclature which has prevailed hitherto in the description of chronic joint diseases, it would not seem unreasonable to suppose that gout has often been mistaken for atrophic and hypertrophic arthritis, and, furthermore, that these two conditions have undoubtedly been reckoned with as etiological hereditary factors in the causation of true gout.

Excessive beer drinking among the poorer class of people and high living with excesses of rich and highly seasoned food and abundant potations of Burgundy and champagne may pave the way for the development of gout, but certainly such conditions are not necessary and are probably only representative of those etiologic factors which lead up to the particular disturbance in metabolism which is designated as gout. Such disturbances may be brought about in many ways.

Pathological Changes.—Like most of the metabolic diseases with joint manifestations, gout develops its lesions slowly and insidiously, though exacerbations in individual joints are not infrequently of relatively sudden onset. The classical location of gout in the joints is in the metacarpo-phalangeal articulations of the great toes, but this is only one of the more common situations. The phalangeal articulations of the fingers and the metacarpo-phalangeal articulations of the hands are very frequent situations for evidences of gout. The larger joints are less frequently concerned, but the knees, ankles, wrists, and elbows are occasionally the seat of gouty deposits.

Gouty tophi in the ears are very common, and, in cases where suspicious gouty joints are found, the presence of tophi in the ears is valuable in confirma-

FIG. 243.—Lateral View of the Foot Showing a Urate-of-Soda Deposit Ulcerating through the Skin over the Head of the fifth Metatarsal. Also shows destruction of the terminal phalanx of the great toe. (Original.)

tion of the diagnosis. Constitutional symptoms are associated with the more active stages of the disease. Such symptoms are headache, malaise, loss of strength, and loss of appetite. Associated with this and with the swelling, pain, redness, and tenderness in one or more of the joints, is an excess of uric acid in the urine. Patients with gouty lesions will excrete a normal amount of uric acid between attacks of gout, but immediately before and during an acute exacerbation an examination of the urine will show a great excess of uric acid, which subsides with the subsidence of the acute symptoms. Frequent exacerbations of joint symptoms are very characteristic of the gouty diathesis.

Differential Diagnosis.—The differentiation of gout from other types of chronic arthritis is sometimes difficult, but is important from the point of view

of treatment and prognosis. The principal conditions from which it is to be differentiated are subacute attacks of rheumatism, infectious arthritis, atrophic arthritis, and hypertrophic arthritis.

From subacute articular rheumatism it is to be distinguished by the greater intensity of the joint inflammations in the rheumatic case; there are a greater tendency to pyrexia, a greater frequency of endocarditis, and a greater liability to the involvement of a larger number of articulations at one time in subacute articular rheumatism than in gout, and the excess of uric acid at the height of the gouty attack and the likelihood of finding tophi, which are of course not present in ordinary articular rheumatism, and the x-ray appearance of the joints, are very helpful in establishing the differentiation. In the rheumatic articulations there is no abnormality in the bone structure, the entire lesion being confined to the soft parts. In gout there are frequently small areas of bone eaten out close up to the epiphyseal line and extending a certain distance down upon the diaphysis. Eventually the cartilage becomes more or less eroded, but this is a later stage in the process than in other arthritides which are characterized by cartilaginous erosions.

From attacks of infectious arthritis which might resemble gout the differentiation is more difficult than from rheumatism. In the infectious polyarthritis the confusion is greater because of the variability of the infections. Some are very severe, some are only mild. Where gout has been established long enough to have made permanent osseous changes in the bones, there recognition of the process is of course not difficult. In the early cases the chief reliance must be placed upon the relatively smaller number of articulations involved in gouty patients, the predilection for the smaller joints in gout and particularly for the classical places in the feet and hands. Gout is more likely to attack one or two small joints in the hands or feet (Figs. 243 and 244), and the infectious arthritides, when they do attack the small joints, generally go through the entire set of articulations. For example, gout in attacking a hand would involve one phalangeal joint, generally the first or second rather than the metacarpo-phalangeal; an infectious arthritis would be more likely to involve an entire set of phalangeal joints and possibly the metacarpo-phalangeal as well. In infectious arthritis we are likely to have an elevation of the pulse rate to twenty or thirty points above the normal rate without any corresponding elevation of the temperature. This is very characteristic of all processes in which joints are concerned where toxic absorption is going on. Excess of uric acid in the urine would also be very suggestive of gout.

In the x-ray examinations of these infectious cases the lesions are wholly in the soft parts about the joint. There are no sodium-urate deposits and no erosions of the bone or cartilage except in the very severe infections where suppurative changes have taken place. In such cases one occasionally sees cartilaginous erosions in infectious polyarthritis.

In the differentiation from atrophic arthritis, a disease which is in all probability a metabolic disturbance, there is less likelihood of confusion. So many joints are involved in this disease and there is so little local inflammatory reaction that one would rarely have cause to suspect gout. The deformities which develop fairly early in the course of the disease are very characteristic. The

Fig. 244.—Shows Enlargement of Metacarpo-phalangeal and Second Row of Phalangeal Articulations, due to urate deposits beneath the skin. One of these has ulcerated through. (Original.)

deformities of gout are purely the result of infiltration of tissue about the gouty joint or are due to the presence of urate deposits. The deformities of atrophic arthritis are the result of luxations of joints brought about through the thinning of the cartilage. Contracture, or even partial ankylosis, may develop in atrophic cases. These are rare in gout. Occasionally in gout an entire articulation may disappear, leaving a hypermobile joint, over which the patient has imperfect muscular control. This is not accompanied by any deformity,

as a rule, and commonly takes place in a small joint, as a terminal phalangeal articulation in a finger or toe.

From hypertrophic arthritis gout is readily distinguished. There are practically no acute local inflammatory signs at any stage of an hypertrophic process. Usually, when the small joints are involved, there are several involved at once, and most frequently they are the terminal row in the hands. The feet are rarely involved; at least, the phalangeal articulations of the toes are not concerned. When a large joint is involved it is generally a hip or a knee, and this joint is not troublesome except when in use. The x-ray appearances are also very different. Hypertrophic lesions in a skiagram show simply an overlapping of the articular line by more or less irregular hypertrophies of the bone at the margin of the articular cartilage. The trochlear surface of the bone is not eroded except in very rare instances, and the restriction in motion and the occasional flexion deformity are due to the mechanical obstruction of the joint.

Treatment.—In the treatment of gout in its constitutional phases the textbooks on internal medicine had best be consulted. The local treatment by mechanical measures is not productive of much result except in rare instances where supports applied to the feet may remove the weight from gouty deposits in the toes, and, by splinting the affected joints, make locomotion in some cases possible, in others relatively comfortable. As was stated at the commencement of this section, however, the purpose in mind was to aid in differentiating this condition from other joint diseases in which mechanical or other treatment is more promising than it is in gout.

XI. HÆMOPHILIA.

Hæmophiliacs not infrequently suffer from hemorrhages into their joints, usually one or other of the larger articulations. Such hemorrhages are not necessarily associated with any considerable trauma, but a simple wrench or twist received while performing the ordinary routine motions of walking or other simple exercise may be sufficient to cause the hemorrhage. The recognition of the condition is, of course, of the greatest importance for both prognosis and treatment. It is unusual that the tendency to hemorrhage does not first manifest itself elsewhere than in the joints. Occasionally, however, hæmarthrosis is the first evidence that the patient has of the existence of the hemorrhagic tendency. In some cases the symptoms are purely those of an effusion into a joint, and it would be impossible to know what the character of the effusion is if the observer were not cognizant of the presence of a hemorrhagic diathesis.

In other cases the oft-repeated effusions of blood into a joint cause some

stiffness and under certain circumstances deformity, this state of affairs being due, of course, to the organization of the clots successively deposited. The character of the fundamental defect in the composition of the blood, preventing its coagulation, is not known, so that there is very little to be said regarding the pathology of this condition. The changes produced within the joints

Fig. 245.—Lateral View of Elbow, showing Distention of the Capsule and Separation of the Articular Surfaces of the humerus and ulna, due to the presence of blood within the joint. (Original.)

by the presence of the effused blood have of course no causal relation to the diathesis, and are purely secondary.

As regards the etiology, also, nothing is known beyond the fact that it is hereditary to a very considerable degree and that the transmission of the hereditary defect is through the male descendants.

In considering this subject it may be well to relate the essential points in the clinical course of two cases recently under observation:

A boy of eight years was brought for consultation because of a limp in the left leg and some pain following a wrench while playing. There was restriction in the motion of the hip in all directions, but this restriction did not seem to be due to muscular spasm. There was no shortening of the leg, and only a slight amount of atrophy of the thigh and calf, more especially of the thigh. There were no night cries, and sleep was not disturbed by pain or other symptoms. On use of the leg

FIG. 246.—Antero-posterior View of the Elbow shown in Fig. 245. (Note in this, as in Fig. 245, the distention of the capsule and consequent swelling of the joint. (Original.)

the boy experienced a certain amount of discomfort, scarcely amounting to pain but causing considerable impairment in function. There was no elevation of temperature, and the boy's general condition seemed excellent. A few years previous to this attack he had been circumcised, and it was only after that operation that the discovery was made that the patient was a "bleeder." He nearly lost his life from this hemorrhage. Since this first attack of hemorrhage into the hip joint he has had several recurrences of bleeding there, apparently of less severity, but as a result of them all the joint motions are now, three years after the onset of symp-

toms, restricted—in flexion about one-third, and in rotation and abduction about one-fourth. There is considerable atrophy, but practically very little impairment of function in the joint. There is no shortening of the limb nor any permanent deformity.

The second case is that of a young man who has had hemorrhages into several of his large joints, notably the knee and elbow. (Figs. 245 and 246.) During a period of four or five years there have been a number of these joint effusions, and during that time one very protracted hemorrhage from an abrasion of the finger, which was not at all serious, and which eventually ceased under compression and styptics applied locally. The patient has had both the knees and the elbow restrained in splints and plaster-of-Paris dressings for long periods of time. The result of the frequent hemorrhage in the knee has been a marked atrophy of the thigh and calf and a very considerable restriction in the motion of the knee joint. The discomfort and disability, with the anxiety which is constantly present in such cases, have made an invalid of him for a number of years.

The physical signs of this condition, as might be supposed, are not pathognomonic apart from the evidence of the diathesis. During the acute stage of the effusion there is a good deal of pain due to the distention of the capsule, and the degree of this is dependent upon the rapidity with which the blood has been poured into the joint. When it has slowly accumulated, it is, of course, less painful than when it has accumulated more rapidly. There is no capsular thickening in the early cases: in the later cases, where repeated hemorrhages have occurred, there may be some thickening. Atrophy, disuse, muscle spasm, and deformity are not as great as where inflammatory conditions are responsible for the joint changes. Discoloration about the joint is significant.

Absence of acute inflammatory signs in the joints speaks against infection as the cause for joint symptoms, and monarticular, non-inflammatory arthritic processes are rare. Conditions which are most confusing to differentiate are: certain low-grade monarticular inflammations; gout of a subacute character; Charcot's disease of the joints, and traumatic effusions into the articulations, the latter including simple synovitis and ruptures of the ligaments within or about the joint; and displacements of the cartilages. This latter group of joint lesions are the ones most difficult of differentiation.

In the *treatment* of hæmophiliac joints surgical rest is the most important factor to insist upon. This assists most effectively in stopping the bleeding and favors the absorption of the clot. This treatment should be continued long enough to insure a cessation of further oozing from the ruptured vessel, as it is the slow continuous oozing which favors organization of the clot and restricts the motion of the joint, thus more or less permanently impairing its function. The chief effort should be to keep the affected joints from becoming flexed or otherwise deformed. Should adhesions develop or deformities occur attempts to overcome either through manipulative procedures should not be made, for fear of rupturing vessels and thus causing further bleeding. The

internal administration of adrenalin or some other styptic should accompany local fixative measures and the application of cold.

The *prognosis* of a local concealed hemorrhage into a joint, in a hæmophiliac, is of course very much better than that of an unconcealed hemorrhage, but this does not alter the grave prognosis of all hæmophiliac conditions. The longer the individual lives the better the prognosis becomes, and if the period of youth and adolescence is passed the outlook is more promising.

TUBERCULOUS DISEASE OF THE BONES AND JOINTS.*

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I. TUBERCULOUS DISEASE OF THE BONES AND JOINTS IN GENERAL.

The recognition of tuberculous disease in the bones and joints dates back to the early part of last century. In 1837 Nélaton wrote a work on "Tubercular Diseases of Bone," and contrasted the disease as it manifested itself in bone with tuberculosis affecting the lungs. Rokitansky, Virchow, and others among German pathologists referred to the frequency of tuberculosis in the bony system and in the joints. Friedlander, Koester, and other observers demonstrated the existence of histological tubercle in the diseased structures about such joints, and yet we find that less than thirty years ago the question as to the true nature of these bone and joint lesions was one of keen controversy. In 1877 Godlee described histological tubercle in "granulation tissue from white swelling of the knee" and looked upon it as a "very lowly organized form of inflammatory tissue" and not of the nature of true tubercle. Croft in 1881 presented several cases of joint tuberculosis before the Pathological Society of London, and his communication was accompanied by some excellent drawings by Greenfield of histological tubercle in both bone and synovial membrane. In his paper Croft gives an extended and interesting summary of the views held at that time by various observers, and indicated the uncertainty which prevailed among surgeons regarding the occurrence of tuberculous disease in joints and synovial membrane. All controversy was finally set at rest when Koch in 1882 discovered the bacillus of tuberculosis, and its presence was demonstrated in the diseased structures about a tuberculous joint.

Anatomical Considerations.—All parts of the skeleton present upon the outer surface a layer of compact bone which is very much denser in consistence

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than the cancellous osseous tissue which lies immediately subjacent. In the short bones the outer envelope of compact bone is of fairly uniform thickness, but in the long bones one finds great variation in this regard. The degree of greatest thickness is attained in the shaft of the long bones, but toward the articular extremity the cancellous tissue is covered by a very thin layer of compact bone. The layer of greater thickness in the shaft gradually fades away into the thin covering of the articular extremity. This fact is well shown in a frozen section through a joint such as, for example, a vertical section through the knee (Fig. 288). The trabeculæ in cancellous tissue are arranged in a definite fashion so as to withstand the forces to which the individual bones may be subjected. An *x*-ray picture demonstrates the existence of this peculiar architecture in such bones as the os calcis or the astragalus (Plate XXVI, Fig. 2). Such bones reproduced by the *x*-ray and viewed stereoscopically show that the trabeculæ are arranged in a double spiral—one system twisting from right to left and the other from left to right. The medullary cavity of a long bone, in which we find the soft cellular marrow, is immediately surrounded by a thin layer composed of delicate trabeculæ of osseous tissue, and this in turn merges gradually into the thick layer of compact tissue which composes the outer covering. The extremity of a bone, where it enters into the formation of a joint, is covered by a layer of articular cartilage, which in the larger joints attains a thickness of about 2 mm. (Figs. 288 and 299). The various joints of the body are surrounded by a ligamentous envelope, the capsule, and this is thickened in various parts and supported by special ligaments which possess individual characteristics and functions in the various joints. The capsule is lined by synovial membrane which becomes attached to the bone at the margins of the articular cartilage. The synovial membrane, which is composed of connective tissue, presents upon its surface patches of cells that are irregularly branched and of an epithelioid appearance. The blood-vessels in and immediately beneath the synovial membrane are very numerous. Tendons or ligaments which pass through the articular cavities are also invested with synovial membrane, and the tendons of muscles acting upon a joint or upon a series of joints in succession are often invested with synovial sheaths, as at the wrist and ankle. In several of the joints folds of synovial membrane pass across the cavity as "synovial ligaments." Other folds of synovial membrane project into the joint cavity; these are very vascular, and usually cleft at their free border as "vascular fringes." Certain smaller non-vascular folds have been described as synovial villi; these occasionally contain cartilage cells and are sometimes made up wholly of fibro-cartilage. The cavity of the joint may be restricted in extent to that of the articular cartilage, or there may be, as in the knee most markedly (Fig. 288), diverticula or pouches lined by synovial membrane which extend beyond the limits of the articular surfaces. It is also well to recall the fact that there exist in many joints interarticular ligaments

which bind together non-articular areas of the intracapsular portions of the articulating bones, *e.g.*, the crucial ligaments of the knee-joint. The crucial ligaments are really portions of the posterior part of the capsular ligament which are isolated by the development of the condyles of the femur. So too the ligamentum teres of the hip-joint is isolated from the capsule by the development of the head of the femur, which expands as a wing on each side of the ligamentum teres, and by fusion of the wings isolates it from the capsule. One may note the existence of pads of fat in many localities between the synovial membrane and the structures which it covers. They fill up gaps and intervals in the joint cavity. Then, again, the existence of interarticular fibro-cartilages or menisci must be borne in mind as important elements in the structure of certain joints, and which must be reckoned with when we have to deal with disease in a joint possessing such structures.

It would appear that the articular surfaces are not in as close contact with one another as is generally believed to be the case. Koenig demonstrated the fact that in a joint like the hip these surfaces are not in contact in the dead subject; he showed that in frozen sections, where the positions of parts are unaltered, there is always found a layer of synovia between the articular surfaces. He endeavored to obtain apposition by firmly wiring the head of the femur to the acetabulum, but found that, even under such circumstances, contact was produced over but a small area of the articular surfaces. Braune and Fischer used screws to press the articular surfaces together and thus secured more extensive contact. It would seem, therefore, that extensive contact of articular surfaces is attained only when considerable pressure is applied, the effect of the pressure being to mould the elastic cartilaginous surfaces upon one another.

The anatomy of a joint in a growing child differs materially from that found in the adult. This fact is recognized in a most striking fashion if one studies the joints at different ages as they appear in frozen sections through the cadaver. Fig. 247 is a section through the body of a child one year old. At this early age the joints are in reality articulations between cartilages, and not between bones. This is well shown in the sections at the shoulder joint and at the elbow, whilst in the hip-joint a small islet of bone is seen to represent the centre of ossification for the head of the femur; again, the bottom of the acetabulum is largely cartilaginous. After the first year of life, however, the ossified epiphyses become more numerous in the skeleton and we then have to do with the epiphyseal disc of cartilage which persists for a variable period between the diaphysis and the epiphysis. These facts are shown very clearly if one compares a section through the foot and ankle of an adult with that through the foot and ankle of a child (compare Fig. 298 with Fig. 299); or sections through the knee-joint at these different ages (*vide* Fig. 287 and Fig. 288). We would therefore insist upon the importance of recognizing the anatomical dif-

ferences which exist in the joint structure of a child as compared with that of the adult—the cartilaginous extremity of a long bone in infancy, later the ossified epiphysis with the persistence of the epiphyseal disc, and finally the adult structure, where all trace of the epiphysis as an individual structure has dis-

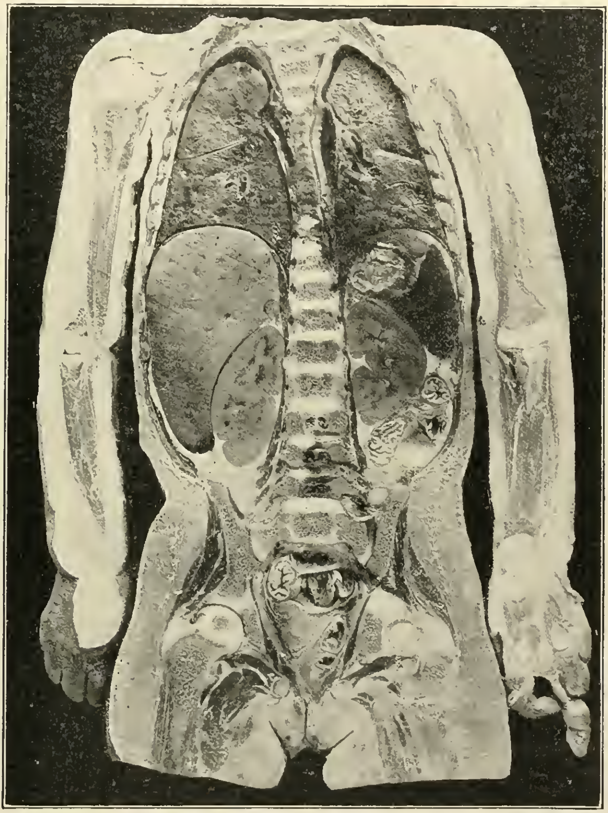

Fig. 247.—Frozen Section through the Body of a Child One Year Old. The hip, shoulder, elbow, and sacro-iliac joints are shown in the section. (Original.)

appeared as the result of its union with the diaphysis. The fact that the growth in length of a long bone is dependent upon the existence of the epiphyseal disc of cartilage was long ago demonstrated by John Hunter in the ingenious experiments which were carried on by him on the bones of growing animals. The truth of this fact is every day illustrated by experience; if the epiphyseal carti-

lage is destroyed, by injury, disease, or by operation upon a joint, then the bone ceases to grow in length at that point. It may be noted here that different kinds of epiphyses are recognized in the human skeleton. There are three varieties: First, those to which we have already alluded, separating the articular extremity of a bone from its shaft; these have been called "pressure epiphyses." Second, there are "traction epiphyses," which form processes for the attachment of muscles, *e.g.*, the great trochanter of the femur, which is separated for a time from the shaft of the bone by an epiphyseal disc, also the small trochanter for the psoas insertion. Third, the so-called "atavistic epiphyses," formed by the union of an element which formerly existed as a separate bone, *e.g.*, those of the ischium and pubis, the coracoid process, the epiphysis of the os calcis (*vide* Fig. 298), and the epiphysis of the olecranon (Fig. 253).

The blood vascular supply to a joint is free. The synovial membrane is the structure which is most freely supplied with blood-vessels. The articular cartilage in a healthy condition is devoid of blood-vessels and apparently depends, for whatever nutrient fluid it requires, on the vascular bone lying immediately subjacent to it, or upon the vascular supply to the synovial membrane which comes into immediate connection with it at its margins. There is, in fact, a narrow, vascular border immediately surrounding the cartilage at its circumference whose vessels are derived from the adjacent synovial membrane; these constitute the so-called *circulus articuli vasculosus*. When the articular cartilage becomes the seat of inflammation, then blood-vessels make their appearance in the cartilage. It is a fact worthy of note that a free anastomosis of the main vessels of a limb occurs in the neighborhood of the articulations. For example, one may cite the anastomosis about the knee and ankle in the lower extremity, or about the shoulder and elbow in the upper extremity. In similar fashion the blood-vessels anastomose about the smaller joints.

The nerves are found to follow for the most part the course and distribution of the articular arteries. The articular cartilage in a physiological condition is devoid of nerves, and yet when it is the seat of inflammation it may become exceedingly sensitive. This characteristic development of sensitiveness in the articular cartilage when inflammation supervenes induces a series of clinical phenomena of importance from a diagnostic standpoint when the joint is diseased. Half a century ago Hilton published one of the most valuable observations that can be made for clinical purposes regarding the nerve supply to joints, and that was with respect to the association in nerve supply between the joint, the muscles moving the joint, and the sensory supply to the skin over the muscles. Take, for example, the circumflex nerve which in part supplies the shoulder joint; that nerve supplies the deltoid muscle, and it also supplies the skin over the deltoid. We see in arthritis affecting the shoulder how these various structures act in harmony. The effect of irritation of the nerve endings in the joint is to induce increased irritability of the muscle controlling

joint movement, and, in addition, to produce increased sensitiveness of the skin over the muscle. We therefore find in the case of an inflamed shoulder that the skin is sensitive to the touch and that any attempt to move the joint is guarded by muscular contraction. Lastly, regarding articular nerves, it must be remembered that there exists an association of nerve supply between the different joints of the same limb. The existence of this relationship sometimes results in certain subjective symptoms of disease which are most misleading unless correctly interpreted. For example, the associated nerve supply of the hip and knee may induce the subjective symptom of pain in the knee when the hip is the seat of disease. The anterior crural, the obturator, and the sciatic nerves are represented in both joints; this anatomical fact explains the misleading symptoms which may be, and frequently are, present in disease.

The strength of an articulation is dependent upon various factors. These may be summarized as: first, the conformation of the articular extremities of the bones; second, the development and strength of the ligaments of the joints; and, third, the support of the muscles which immediately surround the joint and control its movements. These three factors may contribute to an equal degree in the strength of an individual joint, but we frequently find things otherwise, and there are examples of joints which are notably osseously strong, others which are ligamentously strong, and yet again others which are muscularly strong. For example, the shoulder joint is muscularly strong, the osseous conformation of the articular extremities of the bones adds little to the strength of the articulation, and the same might be said of the ligaments; on the other hand, the muscles about the joint are peculiarly effective in strengthening the articulation. The fact is frequently demonstrated by the ease with which dislocation is produced when these muscles are taken at a disadvantage, as in alcoholic narcosis. The acromio-clavicular joint is ligamentously strong and osseously weak; the peculiarity of the muscular attachments here also adds strength to the articulation; thus the deltoid and the trapezius are each attached to both clavicle and acromion, and each would have the effect of maintaining the bones in apposition when in active contraction. Lastly, the hip joint is obviously dependent for its strength largely upon the osseous conformation of the acetabulum which receives the head of the femur; the grip of the head of the bone is also increased by the cotyloid ligament which deepens the socket for its reception. In dealing with the various articulations, therefore, it is well to have in view the peculiar factors which contribute to the strength of the individual joints, and these factors should be conserved as far as possible in our surgical treatment.

It has been assumed that atmospheric pressure is a factor in keeping the joint surfaces in contact. Weber divided all the muscles about a hip joint in a cadaver and then found that the weight of the limb was not sufficient to

draw the joint surfaces apart, but on boring a hole through the bottom of the acetabulum the head at once fell downward. He found, moreover, that a weight of twenty kilos was necessary to overcome the effect of atmospheric pressure sufficiently to pull the joint surfaces apart. It is doubtful if the results of such an experiment could be applied to any other joint. In most joints comparatively small traction force will separate the joint surfaces, the space resulting being filled in by the surrounding tissues or by synovia.

Etiology.—The essential cause of tuberculous disease in the tissues of the body is the bacillus of tubercle; if this bacillus does not enter the body, then tuberculous disease cannot occur. It is both interesting and instructive to study the gradual development of our knowledge regarding the etiology of tuberculosis affecting bones and joints. All caseous deposits occurring in the tissues were called "tubercles" by Laënnec when he wrote on diseases of the chest in 1834. These tubercles of Laënnec were shown by Virchow a few years later to present considerable variation in their origin, and it was not until Cohnheim in 1880 placed definite restrictions on the word "tubercular" that we arrived at limitations which more or less accurately define the field of tuberculous disease as we view it to-day. Cohnheim's definition was: "All is tubercular which, by transferrence to properly constituted animals, is capable of inducing tuberculosis, and nothing is tubercular unless it has this capability." It was not, however, until 1882, when Koch first published his discovery, that the cause of tubercle was shown to be a specific bacillus. Koch defined tubercle as "any growth of newly formed tissue which contains the tubercle bacillus, quite irrespective of situation, histological structure, or distribution." After the discovery of Koch, the development of tuberculous disease in the tissues of the body was more thoroughly understood, and, among other manifestations of tuberculosis, joint and bone disease was more closely investigated. Koch in his original investigations, among other tissues examined, found bacilli present in thirteen cases of tuberculosis of the joints and ten cases of tuberculous affections of the bones. Long before the time of Koch it had been contended that certain manifestations of disease in bone were of an origin similar to that of pulmonary tuberculosis. Thus Delpech in 1816 believed that Pott's disease of the spine was of an origin similar to that of phthisis pulmonalis, and he called the disease "tubercular disease of the vertebræ." Nichet described the tuberculous nature of Pott's disease of the spine in 1835, and Nélaton wrote on "Tubercular Diseases of Bone" in 1837. Later, Virchow, Rokitansky, and others adopted the same view. Investigation of the histological structure of tuberculous tissue demonstrated the almost constant presence of certain characteristic elements, as, for example, the presence in miliary tubercle of giant cells, of epithelioid cells, and of a fine reticulum, each and all of which were described as essential features of the disease. Koester in 1869 was, however, the first to study thoroughly these diseases of the joints histologically

and to recognize fully their tuberculous nature. He examined the synovial membrane in several cases of white swelling of joints, and found in all of them nodules of the size and character of miliary tubercles, having one or more giant cells in their centre, lymphoid elements in their periphery, and a greater or less tendency to fatty degeneration, and he pointed out that so long as the conception of the term "miliary tubercle" was a histological one, so long must these histological tubercles in the swollen synovial membrane be looked upon as true tubercles (Cheyne). Koenig and Volkmann in 1871 made similar deductions from their findings in the histology of the affected tissues about a joint. Koenig ascribed the origin of certain cases of cheesy suppuration in joints to the presence of tuberculous deposits in the synovial membrane, and demonstrated further the presence of histological tubercle in the granulations lining the sinuses about a diseased joint. Observations of this kind paved the way for the recognition of the true nature and etiology of tuberculous disease as it is manifested in joints and in bone. Koch's discovery placed the theory of the origin of these diseases on a firm basis. The bacillus was found in the synovial membrane and in the bones at the seat of disease, and this was proven to be the etiological factor at work. It was found that injection of a pure culture of the tubercle bacilli into a joint directly, or into a nutrient artery of a bone, excites in the bone and joint a fungating disease analogous to that which is now known to be indicative of tuberculosis. It was formerly thought that it was impossible to have an isolated tuberculous joint affection without the individual suffering from general tuberculosis, but it soon became evident that localized joint affection of a tuberculous character was exceedingly common, and the victim of tuberculous joint disease was not necessarily the victim of general infection. Further, it was shown that joint lesions previously called "strumous" or "scrofulous" were all tuberculous in origin and were due to the activities of the tubercle bacillus. It is therefore an accepted scientific fact that the essential etiological factor in the production of tuberculous joint disease is the Bacillus tuberculosis of Koch.

There are certain predisposing causes in the production of tuberculous arthritis, and among these we may first consider *trauma*. Of three hundred and fifteen cases of tuberculous diseases of the bones and joints admitted into the Hospital for Sick Children, Toronto, one hundred and thirteen (*i.e.*, 35.8 per cent) gave a definite history of injury occurring a month or six weeks before the onset of symptoms. It is often possible to elicit a history of injury when one inquires into the cause of a tuberculous joint lesion. This history must not be taken too seriously, however, as the cases which we are considering occur chiefly in children who frequently injure a joint in play without any ill effects. We cannot, therefore, directly connect the onset of tuberculous disease with injury in all cases with certainty, but frequently the sequence of events is so obvious that we must look upon injury as a predisposing cause.

For example, there was admitted to the Toronto General Hospital a lad of seventeen who had tuberculous disease of the ankle, and who gave the following history: Fifteen months previously he had been thrown from his horse and sprained his ankle. He remained in bed for three weeks and then, in spite of continued pain, began to go about; the ankle became swollen and the pain increased. He would rest and resume walking intermittently without permitting complete recovery at any time; finally, twelve months after the accident, he had a plaster cast applied and the foot kept at rest. Three months subsequently, when he came under the care of the writer, he had a typical condition of tuberculous joint disease, with a carious cavity in the astragalus as large as a walnut. In this case the trouble was no doubt initiated by the injury to the ankle joint received by the fall from his horse.

Attention has frequently been called to the fact that slight injury is more likely to cause tuberculous arthritis than more severe injury. Cheyne would have us believe that the explanation lies in the fact that more reparative material is thrown out in the more severe injury; the tissues react to the greater damage more energetically; and he claims that on this account the resistance established to the inroads of the bacillus is greater after a fracture than after a sprain. The writer believes, however, that the explanation is rather to be found in the fact that after a severe injury the part is necessarily kept at rest until repair has taken place, while, on the other hand, in less severe injury, the individual continues to use the injured limb, and a chronic inflammatory condition results which predisposes the injured joint to the inroads of tubercle and maintains conditions favorable for its development.

The relationship of injury to tuberculous arthritis has been demonstrated experimentally. Krause inoculated animals with tubercle bacilli and then injured the joints, succeeding in this way in producing localized lesions in the injured joints; he showed that slight injuries were more likely to induce tuberculous deposit than more severe ones. Krause also found that in a tuberculous animal a fractured bone unites readily without the production of local disease. Similarly, one finds in practice that the victim of tuberculous arthritis who sustains a fracture may have perfect union without the development of tubercle at the seat of injury. Thus one may instance the case of a boy of eight years of age with advanced tuberculous disease of the left knee joint; he fell off a rocking-horse and fractured the left thigh bone about its centre; the fracture was examined under chloroform and carefully adjusted and splinted; union occurred in quite normal fashion without the production of local tuberculous disease.

The existence of tuberculous disease elsewhere in the body predisposes to the production of tuberculous arthritis. So it is we find patients the victims of pulmonary tuberculosis who are not infrequently attacked by tuberculous joint disease. A curious circumstance, too, is illustrated in the sequence of events

sometimes observed in an individual who has long since recovered from a tuberculous joint affection, but who contracts pulmonary tuberculosis, shortly after which the old joint affection reasserts itself. Thus a patient had hip-joint disease with abscess at six years of age, from which he recovered with some deformity and disability of the limb; at twenty-four years of age he contracted pulmonary tuberculosis; the lung affection seemed to clear up for a time while he resided in a sanitarium, but during that time the old hip trouble lightened up afresh, an abscess formed, and a focus of carious bone was found in the femoral neck. The hip trouble had in this case remained quiescent for seventeen or eighteen years, and then reasserted itself when the patient contracted pulmonary tuberculosis; the chest trouble now made rapid progress and soon proved fatal.

The Side of the Body Affected.—Out of 205 cases of patients over five years of age suffering from hip-joint disease and knee-joint disease admitted into the Hospital for Sick Children, Toronto, there were 120 in which the disease was on the right side and 78 in which it was on the left; that is to say, three-fifths had the disease on the right side and two-fifths on the left, or, in other words, there were half as many more affected on the right side than there were affected on the left side. In patients under five years of age the cases were equally divided between right and left. The conclusion from these figures is that after the child begins to run about freely the right limb is more likely to be affected than the left.

The age of the individual as a predisposing factor may now be considered. Tuberculous arthritis is much more commonly met with in the child than in the adult. Statistics proving this fact have been compiled from time to time, and of these one may quote those of Cheyne. The following table shows the percentage proportion of cases of bone and joint disease:

Age.	Total.	Males.	Females.
1– 5	23.2	14.3	8.8
6–10	16.	9.5	6.5
11–15	14.6	9.5	5.
16–20	15.	9.5	5.8
21–25	8.5	6.3	2.
26–30	8.8	5.3	3.3
31–35	4.	4.	. .
36–40	3.	2.4	0.8
41–45	2.	2.	. . .
46–50	2.	1.8	0.4
Above 50	2.	1.	1.

As Cheyne points out, however, this table does not represent the actual risk to life at the different ages indicated. For example, the fact that the largest number of cases presenting themselves for treatment were persons under five years of age may possibly be accounted for by assuming that a larger number of individuals are alive at that age. Cheyne has corrected the

above table after the manner suggested by Fassbender, who calculated the number of persons alive at the different ages, and then indicated the ratio per thousand of the occurrence of such diseases. The following table shows the results, both of Cheyne and of Fassbender, stated in percentages:

Table Showing the Ratio per Thousand (Expressed as a Percentage) of Cases of Disease of the Seven Larger Joints to the Persons Alive at the Different Ages Indicated (Cheyne).

Age	Apparent Frequency.	Real Frequency. (Cheyne.)	Real Frequency. (Fassbender.)
1– 5	232	167	108
6–10	153	134	145
11–15	150	145	113
16–20	153	164	157
21–25	85	98	77
26–30	88	120	109
31–35	41	60	76
36–40	30	48	106
41–45	20	36	66
46–50	20	42	85
50–60	14	17	About 60
60–70	0	0	About 42
70–80	7	33	About 21

It would appear, therefore, from the foregoing table that there is not as great immunity from tuberculous joint disease in old people as might be supposed if one were to study only a table of statistics which has not been corrected as above. The fact remains, however, that we are called upon to treat a larger number of cases in young children than in individuals of any other age. In the Hospital for Sick Children, Toronto, patients are admitted at fourteen years of age and under, and the following statistics have been compiled in such a manner as to show the ages of 310 individuals who had been admitted to the wards as patients suffering from tuberculous joint disease:

Age.	Number.	Percentage Number.
1	2	0.645
2	10	3.2
3	24	8.
4	28	9.
5	39	12.6
6	41	13.2
7	29	9.3
8	22	7.1
9	26	8.4
10	18	6.
11	20	6.4
12	22	7.1
13	15	5.
14	14	4.6

The above table shows a gradual increase in frequency up to six years of age, when the maximum is reached. These figures may be grouped into definite periods as follows:

Age.	Number.	Percentage Number.
1– 5	103	33
6–10	136	44
11–14	71	23

If these figures be taken along with those of Cheyne and Fassbender it becomes obvious that the disease is much more frequent in the first decade of life than at any other period. The statistics of the Toronto hospital would indicate that in children the disease is most common about the fifth and sixth years.

There is also apparently a distinct relationship between the age and the particular joint affected. During the first decade of life, for example, the hip and knee are more likely to be affected. The following table from Cheyne shows the relationship in question:

	First Decade.	Second Decade.	Third Decade.	Fourth Decade.	Fifth Decade.
Hip	30.2	20.3	4.8	..	12.5
Knee	29.5	22.8	18.2	36.6	6.2
Ankle	5.4	5.9	3.6	3.3	12.5
Tarsus	4.6	5.9	8.4	3.3	18.7
Shoulder	.	1.6	4.8	..	.
Elbow	6.7	9.2	6.	13.3	18.7
Wrist	.6	8.4	15.8	13.3	6.2
Fingers	1.5	4.2	2.4	..	..
Ribs	..	..	1.2	10.	12.5
Os calcis	2.6	2.4	2.4	3.3	..
Odd bones	6.7	3.2	3.6	..	..
Spine	12.	15.2	28.	20.	12.5

Clinical experience leads to the conclusion that the age of the patient has a marked effect on the severity of the disease. This is noticed in the occurrence of suppuration. Thus Cheyne's statistics show that during the first decade 66 per cent, during the second decade 74.5 per cent, and during the third decade 86.2 per cent, suppurated. Cheyne points out, however, that the percentage statement is too high for all cases, as the statistics were compiled from the indoor patients and did not include outdoor cases, most of which were non-suppurative. Nevertheless, it illustrates the fact that suppuration is more likely to occur as age advances.

In considering predisposition we must include *sex* as a factor. It would appear that males are more liable to tuberculous arthritis than females. Cheyne's statistics show that in 386 patients under treatment in hospital, 251, or 65 per cent, were males, and 135, or 35 per cent, were females. There is some varia-

tion in the joint affected in relation to sex as shown from the following table from Cheyne:

	Hip.	Knee.	Ankle.	Tarsus.	Shoulder.	Elbow.	Wrist.
Males......	59.7	57.6	81.9	85.8	50	74.3	75.9
Females....	40.3	42.4	18.1	14.2	50	25.7	24.1

The disease is more severe in males than in females. This is the case whether we test the matter by the severity of the measures required for cure, by the results of treatment, or by the frequency of suppuration (Cheyne).

The Influence of Heredity.—There can be no doubt of the facts that tuberculosis frequently attacks different members of the same family, and that other families are peculiarly free from it. The explanation of this circumstance is not by any means established by saying that the disease is inherited. In fact, we may assert that the disease itself is never inherited. On the other hand, the predisposition to the disease may be handed down from parent to offspring. Some individuals seem to have a more diminished power of resistance against tuberculosis than others, and the constitutional conditions which characterize that diminished power of resistance would appear to be inherited.

Out of 315 cases of tuberculous disease in bones and joints admitted to the Hospital for Sick Children, Toronto, 131 (*i.e.*, 41.5 per cent) gave a history of tuberculosis somewhere in the family tree. Then again, 73 of these cases (*i.e.*, 23 per cent) had tuberculous parents. It may be further mentioned regarding these 315 cases that 156 (about 50 per cent) had been delicate from birth. The remainder were fairly strong, or else the history had omitted to mention anything about the previous health.

The habit of life of the individual may be a predisposing cause. Bad hygienic surroundings render the individual more liable to the disease. These may consist of dark, damp, and badly ventilated quarters and insufficient and unsuitable food. In speaking of the quality of the food, the following interesting and suggestive account of Bidder's views is given by Cheyne: "Bidder, in speaking of the treatment of these diseases, lays great stress on the avoidance of substances rich in potash, and also of starchy materials, and strongly advises the employment of albuminous foods rich in soda and fat. A probable confirmation of this view is the noteworthy fact that tuberculosis is, as a rule, very common in herbivorous animals, and can usually be very readily induced in them, while, on the other hand, it seldom occurs in the carnivora"; *e.g.*, rabbits and guinea-pigs are easily inoculated with tubercle, but dogs and cats are comparatively insusceptible to the contagion. Villemin first demonstrated this fact in 1866. Man, who employs a mixed diet, stands midway between these two groups in his susceptibility to this disease, tuber-

culosis being more often local and less virulent than in the herbivora, while it is much more frequent and destructive than in the carnivora. In this way also Bidder explains the much greater frequency of tuberculous disease in the western part of Germany than in the eastern, although the density of the population is greater in the latter; it appears that the inhabitants of Eastern Germany employ less vegetable diet than do those of the west, and eat large quantities of salt meat.

Pathology.—The term "tubercle," meaning a nodule, or little node, was originally applied by Laënnec to the gross appearances presented in tissue the seat of a tuberculous lesion. Two varieties were recognized: the "gray or miliary tubercle," approximating a millet seed (milium) in size; when caseation occurred in these they changed in color and were then called "yellow tubercles." At a later period, when the microscope revealed the fact that these gray and yellow tubercles were composed of aggregations of minute, invisible, translucent masses, each composed of cells grouped in a characteristic fashion, a third variety was described for which the name "histological tubercle" or "submiliary tubercle" was provided. It must be clearly understood that all these terms are applied to different manifestations of the same process due always to the same etiological factor, namely, the bacillus of tuberculosis which produces, when introduced into the body, an inflammatory neoplasm in the tissues.

The histological features characteristic of tubercle consist of a special grouping of cellular elements. There is a giant cell, situated usually in the centre of the tubercle, containing many nuclei. These nuclei are usually grouped in the form of a horseshoe within the cell; they may be collected at one end of the cell, or occasionally they are found scattered irregularly through the cell. The cell possesses at its periphery many fine processes which pass out among the other cellular elements and are lost in a fine reticulum which pervades the whole tubercle. Surrounding the central giant cell are a series of cells which, because of their appearance, have been called "epithelioid cells." A peripheral zone of cells surrounding the epithelioid cells consists of leucocytes and these constitute the "small round cells" of the tubercle. The "reticulum" of tubercle has been described by some observers as simply pre-existing connective tissue invaded and pushed aside by the new cells; by others it is described as composed of processes of the epithelioid cells. A thickening of the reticulum at the periphery may constitute a more or less defined capsule for the tubercle. In the meshes of the reticulum are found the cellular parts of the tubercle. We may therefore speak of four elements in the tubercle—the giant cell, the epithelioid cell, the leucocyte, and the reticulum.

The type of cell arrangement which we have described for tubercle may be departed from in certain cases, and the tuberculous tissues may exhibit a different histological arrangement from that described. For example, the giant

cell may be absent, or, again, changes may have supervened to produce a fibrosis of the tubercle, and then a fibrous nodule exists as the manifestation of the activities of the tuberculous virus in the tissues.

Again, it may be noted that a condition of more or less infiltration of the tissues by the tuberculous process, without the manifestation of discrete tubercles, has been observed. In these cases there is a massing of the epithelioid cells in more or less columnar-shaped groups, in which bacilli are often found in large numbers. The term "tuberculous infiltration" has been applied to this condition, and from a study of its histological characters Cheyne was inclined to look upon the epithelioid cell as the essential histological element of tubercle.

Different views are held as to the origin and the significance of the giant cells. It is held that they represent lymph spaces in which a coagulum has formed, the nuclei being derived from the epithelium of the wall of the space. Baumgarten believes that the giant cell represents an overgrown cell in which active division of the nucleus has occurred without corresponding division of the protoplasm of the cell, and that this peculiar effect is produced by the irritation of the bacillus in its interior. It must be remembered that giant cells are not peculiar to tubercle; thus they are found in bone marrow, in granulation tissue, in gummata, sarcomata, actinomycosis, in inflamed serous membranes, and in the placenta. The epithelioid cells are two or three times the size of the white blood cells, they often become caseous, but in the process of healing they appear to atrophy and become converted into fibrous tissue. As a fact, the epithelioid cells are fibroblasts, and as such they tend to form fibrous tissue unless they are overtaken by the process of caseation. The leucocytes are present as a barrier zone around the central aggregation of epithelioid cells. The presence of the leucocytes here is simply a manifestation of the reaction of the tissues to the presence of an irritant, producing this characteristic feature of an inflammatory process.

In consequence of the fact that a tubercle is non-vascular it sooner or later undergoes retrogressive changes and becomes fatty, necrotic, and caseous. While these changes may be readily observed in tubercle under the microscope, we have frequent manifestations of this necrotic tendency in the gross anatomy of tuberculous tissues. Where a number of tubercles have grouped themselves together it is obviously the central portion of the mass which is most likely to suffer from lack of nutrition, and there we find retrogressive changes going on, with the production of a necrotic centre in the tuberculous tissue; lime salts may be deposited in this, producing some degree of calcification. The central necrotic mass may liquefy and form what is known as a tuberculous or "cold" abscess.

The presence of the specific virus of tubercle may be demonstrated in the affected tissues. It is not always easy or possible to find the bacillus, but

with appropriate methods of staining, and after careful search, they can usually be found. Cheyne accounts for the fact that the bacilli can be demonstrated only in small numbers, and sometimes not at all, by suggesting that they are growing slowly and with difficulty, and that their staining reactions differ at different periods of their existence. It would appear that our present methods of staining do not justify us in drawing conclusions as to the number present. Bacilli are found in the giant cell and in and among the epithelioid cells, but they are not at all found in the inflammatory cells, *i.e.*, the leucocytes. The bacilli are found in largest numbers in the giant cell, and where they are few in number they are usually restricted to the giant cell.

The gross appearance of the lesions which are present in tuberculous arthritis is sufficiently characteristic. In many cases the synovial membrane becomes uniformly thickened and possesses a pulpy, gelatinous consistence; if incised, the surface of the section is usually of a gray clay color. The inner surface becomes covered with a thick layer of jelly-like fungiform granulations, or bunches of these hang from the vascular fringes. Occasionally these appear as a great mass of synovial villi of jelly-like consistence hanging free in the joint cavity, and, in the knee, for example, forming a very considerable amount of the thickening which is so observable on examination of the affected joint. While the usual form in which we find the disease manifested in synovial membrane is in this diffuse, pulpy thickening of that structure, occasionally the disease may be more limited and may present itself as one or more isolated nodules. Then, again, there is the acute miliary manifestation of tubercle. Koenig describes miliary tubercles in synovial membrane in cases of acute general tuberculosis. Lastly, there is a tuberculous involvement of the synovial membrane described by Koenig and Volkmann, in which the joint contains fluid, but there is no marked thickening of the synovial membrane to start with, although the disease is primarily synovial; subsequently swelling of the synovial membrane comes on, and then, quite likely for the first time, the true nature of the condition is recognized. Koenig has examined these cases at an early stage and states that there is a formation of a thin layer of tubercles on the surface of the synovial membrane, along with a slight amount of chronic inflammation. In the condition known as "empyema tuberculosum" a very similar condition is present, but caseous pus is found in the joint cavity, while the synovial membrane is not thickened; these cases are more commonly met with in old people. A very similar condition is found in some cases after a caseous deposit has opened into a joint. (Cheyne.)

In the diffuse thickening of the synovial membrane, which is by far the most usual form observed when these patients are first seen, or when we open a joint for tuberculous disease, there are certain characteristic appearances with which we become familiar and which we have described, but the area of actively growing tubercles may be uniformly distributed over the

inner surface of the membrane, giving us the gross appearance of fungiform, jelly-like granulations projecting into the joint cavity; this is supported externally by tissue, the seat of a non-infective chronic or subacute inflammation, and presenting a very considerable degree of thickening, in which tubercles are absent. This outer layer of thickening is of firm consistence, in marked contrast to the inner lining of soft tuberculous material. It is an example of a chronic progressive fibrosis surrounding the area of tuberculous activity. If the disease continues to progress, the outer area of inflammatory thickening may be invaded until a considerable mass of soft and often caseous material is found replacing the normal synovial membrane. Cheyne considers that these cases of invasion of the synovial membrane from within are in reality secondary lesions and are produced as the result of a primary deposit in the bone reaching the joint cavity freely and rapidly, causing infection over the entire surface of the synovial membrane. It would appear, however, that those cases which present the greatest degree of synovial thickening are primary synovial lesions, and in these the deposit of tubercles may appear in any part of the substance of the membrane, or even in the sub-synovial tissue. From this starting point there is soon an invasion of the entire membrane by the tuberculous growth, preceded by inflammatory swelling and infiltration of the tissue.

The condition of limited tuberculous involvement of the synovial membrane is comparatively rare. Koenig, Riedel, Cheyne, and others have described nodular, often polypoid, growths occurring generally in the knee. One or more firm nodules may project from some part of the capsule, generally in the pouch above the patella; the condition is not infrequently accompanied by hydrarthrosis. The entire synovial membrane becomes reddened and often thickened, and the fluid within the joint frequently contains rice-like bodies. Histologically the nodules are found to contain tubercles closely packed together.

The pathological changes which occur in the bone in tuberculous disease may now be described. The bone is first affected in the cancellous tissue, so that we find the earliest manifestations of the disease in the cancellous ends of the long bones. The tuberculous deposit may be found in the epiphysis or in the diaphysis, *i.e.*, on either side of the epiphyseal cartilage in the growing child. Not infrequently the disease spreads from the cancellous bone to the epiphyseal cartilage, and thus the cartilage becomes secondarily involved and destroyed, or, on the other hand, the disease may first separate and then lead to the destruction of the articular cartilage. At certain stages of the disease it is common to find the cartilage completely separated, as it overlies the tuberculous deposit in the bone. At later stages the articular cartilage is honeycombed, becoming absorbed and perforated at various points. Finally, the cartilage may almost completely disappear. We shall consider the changes

which lead to the destruction of the cartilage later, but in the mean time let us consider the histological changes which may be studied in the bone.

The manifestation of histological tubercle is similar to that described earlier in this article, modified only by the peculiarities of the osseous tissue in which it now develops. The effect upon the bone, however, leads to certain characteristic changes. In the earliest phases we have the tubercles occurring in isolated portions of the cancellous tissue, and, as giant-celled systems make their appearance, the trabeculæ of bone forming the network of the spongy texture becomes greatly atrophied; an inflammatory process surrounding each focus leads eventually to the formation of granulation tissue; in places the osseous trabeculæ are destroyed, neighboring foci of tubercle merge together, the centre of the tubercles thus grouped becomes necrosed and fatty, while the bony trabeculæ in this area entirely disappear, and thus an area of the cancellous tissue, varying in extent in different cases, becomes greatly altered and is replaced by masses of tissue in which one can distinguish caseation in the midst of a tuberculous focus; around about the central caseous area one can distinguish actively growing tubercles, and beyond that, again, forming an encircling zone, we find inflamed bone where the absorption of bony trabeculæ is going on and where that tissue is being replaced by granulation tissue. The bone is thus softened and loses its firmness to a large extent; a probe introduced into it readily penetrates the cancellous tissue and thus we have the picture of what we are familiar with as "caries" or "ulceration of bone." The term caries has long been applied to this broken-down and disintegrated condition of the bone in which the osseous trabeculæ are softened and rarefied, while the interstices are filled with half-purulent material containing much granular and oily débris. The atrophy which occurs in these cases is often very extensive in amount and extreme in degree, so that if a specimen of such diseased bone were dried the osseous trabeculæ would be found to be represented by a most delicate tracery or network of fine bony spicules and the medullary spaces unduly enlarged. This constitutes the condition of "rarefying osteitis." In the immediate vicinity of the tuberculous focus the bony trabeculæ may be thicker than normal, thus presenting the condition of sclerosis, and in this position, too, the chronic inflammatory process may lead to the formation of fibrous tissue. If the disease progresses, then the tuberculous process invades the area of inflamed bone which surrounds the primary focus, and this in turn undergoes changes similar to those described, until eventually the disease reaches the surface of the bone. It may thus gain the articular surface, and may there invade the articular cartilage; eventually this is perforated and the joint becomes involved. This becomes manifest by the presence of fluid in the joint, which is at first merely an inflammatory exudate, but soon appears as caseous pus, which collects to a variable amount in the joint cavity. When the tuberculous process spreads toward the epiphyseal

cartilage, the irritation at that point not infrequently leads to increased activity in the changes which are going on there in the growing bone, and this results in the manifestation clinically of increased length of the affected bone. (This occurs particularly at the knee joint.) Finally, the epiphyseal cartilage may be destroyed in the process. Then again, the disease may reach the surface of the bone immediately under the reflection of the synovial membrane over the bone. In such cases the synovial membrane becomes invaded. At first it is the seat of chronic inflammation, and this in turn becomes invaded by the tuberculous process. Thickening and destruction of the synovial membrane occur, as has been described. In turn the ligaments about the joint become the seat of disease; these become softened and may be completely destroyed where they are invaded. An abscess may form and come to the surface or open into the joint. By this means, in a case which advances to extensive destruction of tissue, there may be complete disintegration of the joint structure. The disease may, however, reach the surface of the bone quite beyond the attachment of synovial membrane or ligament, and under such circumstances the soft tissues may become invaded next to the surface of the bone and outside the joint, and may there lead to the formation of an extra-articular tuberculous abscess.

The chronic inflammatory process which surrounds the tuberculous focus may lead to a thickening of the osseous trabeculæ to such an extent as to constitute a sclerosis of the bone. This may continue while the tuberculous focus has become quiescent: the tubercles may disappear and their place may become occupied by granulation tissue, which in turn is transformed into fibrous tissue. Thus it is that cases of tubercle in bone which have undergone spontaneous cure have the infected area replaced eventually by sclerosed bone and fibrous tissue.

Another condition of affairs sometimes develops, viz., one in which the vitality of the bone at the seat of disease is destroyed and a mass of cancellous bone perishes and is separated as a sequestrum. An example of this is well shown in Fig. 248, where in a frozen section a sequestrum is apparent, situated in the head of the astragalus. The section was made through a tuberculous ankle. In the condition of necrosis in tuberculous disease it would appear that sclerosis precedes the death of the portion of affected bone, and as the sequestrum is being separated one finds in the soft tissue surrounding the sequestrum numerous actively-growing tubercles. These may caseate and form pus as the process still further extends, and so we have the sequestrum lying in a pus cavity, the walls of which are represented by cancellous tissue, which is the seat of tuberculous deposit, or which very often becomes sclerosed as the result of condensing osteitis, as in the case figured; surrounding this is an area of rarefying osteitis. The sequestra are of various shapes and sizes.

A rare manifestation of tubercle in bone is that of acute diffuse miliary

tuberculosis. This is said to occur quite apart from any large deposit. It is of unusual occurrence except in cases of acute general tuberculosis.

Having now discussed the changes in synovial membrane and in bone, we may proceed to describe the changes which occur in cartilage.

Here again the changes are those which result from a chronic inflammatory process. It would appear that, as the tuberculous disease progresses in the cancellous bone and approaches the articular cartilage, the latter soon shows indications of inflammation. The congestion of the cartilage is evident at an early stage, and this is the more marked because of the fact that cartilage in its normal condition possesses few blood-vessels, and instead of the usual

FIG. 248.—Tuberculous Deposit in the Astragalus. There is a small sequestrum lying in a cavity, the walls of which are formed by dense sclerosed bone. The patient had had the ankle joint excised for tuberculous disease eleven years previously. (Original.)

bluish-white appearance it now becomes pink in color and is obviously invaded by the development of new blood-vessels in its substance. The cartilage cells undergo a change; they proliferate, the cartilage matrix becomes absorbed, and the normal structure becomes replaced by granulation tissue. The cartilage thus becomes perforated in spots, giving us the characteristic worm-eaten appearance which is familiar to those who have had the opportunity of seeing the interior of a tuberculous joint at this stage of its existence. In this granulation tissue tubercles are found, and eventually, in patches, the whole thickness of the cartilage disappears from the articular extremity of the bone. In this stage portions of the cartilage may be found still adherent to the bone beneath, and the margins of the articular surface usually continue to present remnants of the cartilage after it has completely disappeared elsewhere. A

somewhat different series of events is observed when the cartilage becomes secondarily affected from a primary deposit of tubercle in the synovial membrane. Here, at the margins of the cartilage, a congestion occurs, and a layer of granulation tissue develops on the surface of the cartilage; this may proceed to the formation of fibrous tissue. Histological tubercle occurs in this granulation tissue, and gradually, by a process similar to that already described, the inflamed cartilage becomes the seat of tuberculous deposit and finally is destroyed. It would appear, from the researches of many observers, that the cartilage is never the primary seat of tuberculous disease. This is true for hyaline cartilage, but it is possible that primary tuberculous infection may occur in fibro-cartilage, as Kocher has described in the semilunar cartilages of the knee joint. It may now be added that the disease may occur primarily in synovial membrane, and then, having invaded the cartilage, the underlying bone may in turn undergo tuberculous change; and thus beneath a patch of diseased cartilage we may find inflamed and softened bone, or a portion of cancellous tissue exhibiting caries, which focus of infection is surrounded by a layer of condensing ostitis, and this in turn by rarefying ostitis.

Fig. 249.—Extreme Atrophy of the Femur in a Child whose Limb had been Amputated for Tuberculous Disease of the Hip. (Original.)

It is quite remarkable that the condition of rarefying ostitis should be so marked at quite a distance from the actively growing tubercle, and yet we find here a manifestation in bone which is comparable to the non-infective inflammatory process which, as we know, surrounds tuberculous deposits in the soft tissues of the body, *e.g.*, in a tuberculous lymph node. Moreover, as Cheyne has pointed out, in many cases a layer of comparatively normal cancelli separates the carious part from that where the rarefying ostitis is most marked.

The extent of the atrophy of bone in tuberculous arthritis is often remarkable, and is due, no doubt, to the same causes which produce the atrophy of the muscles; the nutrition of the whole limb about a tuberculous joint is profoundly affected. Fig. 249 represents the femur of a child who suffered from hip-joint disease, and Fig. 290 is an x-ray picture from a case of disease in the knee joint showing marked atrophy of the bones of the leg and of the thigh.

In considering the changes which occur in tuberculous affections of the bones at points far distant from the joint, reference may be made to the fact that tuberculous disease may manifest itself immediately beneath the periosteum, constituting a form of chronic periostitis which may lead to extensive destruction of bone. This is the form which is so familiar in the ribs, where the trouble spreads beneath the periosteum and occasionally leads to extensive and often multiple foci of tuberculous deposit, perhaps restricted to one rib, but frequently several ribs are so attacked in the same individual. Then again, the disease may begin in the medulla of the bone, constituting a tuberculous osteomyelitis. This is found in young children at times in the form known clinically as "strumous dactylitis." The processes are the same as those described, and they result in a thickening and enlargement of the bone (*e.g.*, in the phalanx), with deposit of new bone under the periosteum. The effect of this is to produce a characteristic fusiform enlargement of the bone, giving it the appearance as if it were ballooned out and suggesting the name, which older authors gave it, of "spina ventosa."

The term "caries sicca" has been applied to an unusual form of tuberculous disease in the joints. It chiefly affects the shoulder joint, but sometimes occurs in the hip and more rarely in the knee. (Cheyne.) There is no swelling such as usually appears in tuberculous joint disease of the ordinary type, but on the contrary all the structures about the joint show an increasing and progressive atrophy. The peculiarity of the disease is the formation of new tissue. which shows a great tendency to shrink and to form dense fibrous tissue (Cheyne.) It results eventually in destruction of articular cartilage with obliteration of the joint cavity and firm ankylosis of the joint. Pain is usually severe, but there is, as a rule, no rise of temperature, and there is seldom suppuration.

Among the rarer forms of tuberculous bone disease Cheyne describes "diffuse condensation of bone in connection with tuberculous disease." In a typical case in the femur he describes the following sequence of events: "A tuberculous deposit formed near the surface of the external condyle of the femur and led to the production of a sequestrum. Around this deposit condensing ostitis occurred and extended over the bone for a considerable distance, but before long fatty degeneration of the inflammatory products took place and reached an extreme degree, and calcareous salts were also deposited in this fatty material. Where this degeneration extended quite up to the cartilage the latter was deprived of nutritive material and became rubbed or broken away at the surface. The obstinacy of these cases is thus due to the fatty degeneration of the tissue and not to the tuberculous infiltration of the bone."

The same author describes diffuse softening of bone in which the very opposite condition to that just mentioned exists. The osseous trabeculæ in the

epiphyses and in the medulla of the bone are destroyed; the medullary cavity is enlarged and filled with red marrow in which tubercles are found in considerable numbers. There are apt to be multiple lesions present, so that several bones are affected, and general tuberculosis is likely to supervene. The condition is a rare one.

Tuberculous Abscess (Chronic Abscess).—Abscess formation may result from the development of tuberculosis in the tissues. The sequence of events is easily accounted for. At first the tuberculous lesion manifests itself by the production of isolated tubercles; these become grouped, and, as they tend to undergo retrogressive changes, the tubercles toward the centre of the group become caseous. The invasion of the surrounding tissue by the tuberculous process continues, and the area of disease gradually increases. In the centre of the caseous mass liquefaction occurs. This is apparently due to an effusion of serous fluid which finds its way into the necrotic centre from the surrounding area of congested and inflamed tissue. The fluid which thus invades the necrotic centre is accompanied by leucocytes, but these are not nearly as numerous as those found in the pus of an ordinary septic abscess. We may now imagine that the process still further advances and the abscess enlarges. This is accomplished by further spread of the actively growing tubercles at the circumference, the older tubercles in turn becoming necrosed and fatty and forming a layer of caseous material immediately internal to the newly formed tubercles at the circumference. The central cavity enlarges, the pus increasing in amount. This pus contains, in addition to leucocytes, an amount of necrotic débris that has become freed from the caseous material which forms its immediate surroundings. The picture which presents itself is that of a mass of disease developing in the tissues, with pus at the centre surrounded by caseous material, and this in turn surrounded by tissue containing tubercles. Add to this the halo of non-infective inflammation which immediately surrounds the whole diseased area, and we find that we can distinguish well-defined zones in the affected tissues. These zones, from within outward, would consist of: first, a central zone of pus containing a few leucocytes and more or less necrotic débris; second, a zone of caseous material; third, a zone of actively growing tubercles; fourth, a zone of inflamed tissue (*vide* Fig. 250). In the fourth zone described we find that the process of inflammation may go further than merely the production of granulation tissue, for we find that, as the abscess enlarges, there is developed about it a very definite and frequently much thickened wall of fibrous tissue; the fact being that the chronic inflammatory process has gone on from the production of granulation tissue to that of fibrous tissue, so that a well-defined abscess wall is formed. As this abscess spreads, it does so by a very definite method. The newly formed fibrous-tissue investment is readily invaded by the formation of new tubercles within it, and the fibrous tissue thus disappears, while a new and more extensive area of inflam-

mation invades the tissue at the circumference. Fresh necrosis of tubercles occurs toward the centre, and the inner zone of caseous material becomes detached and partly absorbed, and an increased amount of fluid accumulates.

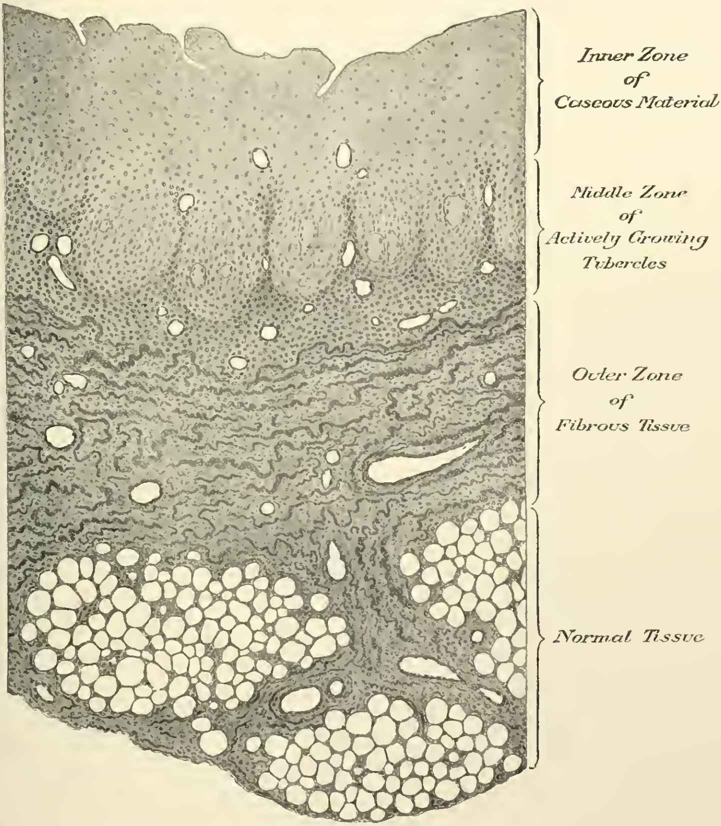

Fig. 250.—Section through the Wall of a Tuberculous Abscess. The specimen from which the section was made was removed from a tuberculous abscess which developed in connection with disease of the knee joint. A photograph of the case is shown in Fig. 294. The portion of the wall removed lay immediately under the incision made when the abscess was opened, and thus constituted a part of the abscess wall farthest removed from the diseased bone. (Original.)

Thus it is that the wall of an abscess of this character exhibits at any point of section the various layers described, and the author has frequently demonstrated this to be the case. A somewhat interesting comparison may be instituted between the zones described and those of the histological tu-

bercle, in which we have the central zone consisting of the giant cell with its many nuclei, then the zone of epithelioid cells, surrounded by the zone of leucocytes and the area of inflammation. The circumferential zone of inflammation is no doubt due to the same cause in both instances, namely, the reaction of the tissues to the presence of an irritant: in the one case the presence of a tubercle, or a group of them; in the other the presence of a larger or smaller mass of diseased tissue constituting the more complicated and probably more extensive structure of the developing tuberculous abscess.

These processes may be studied in osseous tissue modified somewhat by the nature of the bone structure, and thus we may have chronic abscess in the bone itself. (*Vide* Fig. 254.) These abscesses are frequently found in tuberculous joint disease invading the cancellous tissue. They tend, however, eventually to come to the surface, and may thus extend to and invade the joint cavity after destruction of articular cartilage has been brought about. It is not uncommon for these abscesses which have their origin in bone to find their way to the surface of the bone beneath the synovial membrane or the periosteum and then to continue to spread in the soft tissues. The spread of such an abscess may be continued to an unlimited extent as it increases in the soft tissues. It tends, however, to spread in the direction of least resistance, and is found to develop along fascial planes or between muscles. A well-known example of this is found in the psoas abscess, with which we are so familiar, which spreads under the psoas fascia until eventually, from an original focus of disease possibly far up in the dorsal spine, the abscess, passing under the internal arcuate ligament, continues its course downward under the psoas fascia until eventually it may point in the thigh below Poupart's ligament.

An abscess of this character may be extremely slow in its development, so that occasionally one has had such cases under observation for months while the increase in size has been very gradual. Such abscesses tend, however, eventually to come to the surface and may point and rupture spontaneously. On the other hand, the author has known them to disappear spontaneously. In this connection may be cited the example which was afforded the writer in a case of tuberculous disease of the dorsal spine in which laminectomy had been performed to relieve paraplegia. At the operation an abscess was found to have opened into the spinal canal and was pressing upon the cord. The abscess extended into the posterior mediastinum, and, as one could not evacuate it, an attempt was made to drain it. The contents of the abscess were fluid at the time, as evidenced by the fact that respiratory movements produced an ebb and flow of the pus as it presented itself in the neural canal. The patient died six weeks after the operation, of tuberculous meningitis. At the autopsy the abscess cavity was found in the posterior mediastinum filled with necrotic material, but no pus; a culture proved this to be sterile. The course of this case would suggest the possibility that tuberculous abscesses, when they

undergo spontaneous cure, go through changes which would be represented by a sequence of events beginning with an absorption of the fluid contents, and subsequently characterized by a disappearance (by absorption) of the débris, which in turn fills the cavity, the tubercles in the mean time ceasing to multiply and the disease thus becoming quiescent.

A typical case of tuberculous abscess is shown in Fig. 294. The abscess developed in a child of six years of age; it was situated to the inner side of the knee and was opened under aseptic precautions, healing taking place by first intention. The case illustrates the formation of an abscess that came to the surface outside the joint, and in no way implicated the joint cavity nor restricted the movements of the joint. The piece taken out for microscopic section (shown in Fig. 250) was excised at a point as far removed from the bone as possible and represented the wall at its most superficial part, and yet we find the typical zones of the abscess wall here represented.

Changes in the Ligaments about a Tuberculous Joint.—The ligaments become the seat of an inflammatory process which at first is non-infective in type. The result is that the ligaments become soft and yielding and permit dislocation of the joint in varying directions. This, for example, is very noticeable at the knee, where we often find dislocation backward of the head of the tibia with rotation of that bone outward. The deformity is produced by the action of muscles. The stability of the joint is impaired by the implication of the ligamentous structures in the inflammatory process, and then dislocation becomes possible and readily occurs. In long-standing progressive disease the ligaments may themselves become the seat of tuberculous lesions and may become destroyed.

Changes in the Muscles About a Tuberculous Joint.—One of the most characteristic phenomena which may be observed in connection with tuberculous joint disease is muscular atrophy. This is so marked a feature that in a suspected case, if we are unable to determine the existence of muscular atrophy, we may practically exclude tuberculous disease from our diagnosis. The cause of this atrophy is often attributed to disuse of the affected limb, but we cannot always explain it thus. In the earlier stages of tuberculous joint disease the muscles controlling the movements at the affected articulation are not in a condition of rest; on the contrary, they are more or less constantly in a condition of tonic contraction and are always on the alert to protect the joint from movement. Otherwise expressed, we may say that the muscles are active agents in maintaining the fixation of the joint. In spite of this fact the muscles atrophy. The probable explanation of muscle atrophy in tuberculous arthritis is to be found in some nerve influence (possibly reflex) that interferes with the nutrition of the muscles of the limb in which the joint trouble is located. The

muscle diminishes in bulk, and the contractile elements are replaced by fat and fibrous tissue.

Prognosis.—The possibility of effecting a permanent cure in tuberculosis is a question which has received much attention from time to time, not only in connection with tuberculous diseases of the bones and joints, but also in similar affections of the lungs and other organs of the body.

The disease may remain quiescent for many years, as in the case already referred to in this article (page 567), where tuberculous hip trouble was dormant for eighteen years and then reasserted itself. Nevertheless, numerous instances exist where the disease has ceased and the individual has subsequently lived for many years without any further manifestation of the tuberculous affection. It is probably incorrect to say the disease was "dormant" in a case of recurrence, because the idea conveyed by such a phrase would not be quite consistent with the facts as we know them. Take, for example, the case of hip-joint disease which has been arrested after two or three years of treatment by rest; we may assume that in such a case the destruction of tissue has been great and a cure has eventually been effected largely by the substitution of fibrous tissue for tuberculous tissue. Now this scar tissue, if we may call it so, is more likely to become infected by a fresh inoculation of tubercle than normal tissue, and hence, under favorable conditions, the individual may have a recurrence of the disease in the region previously attacked. With this understanding of the results obtained, one may hold that it is quite correct to speak of a cure, and we may imagine that the disease may be entirely eradicated from the system, but we must also recollect that the individual who has once had tuberculous joint trouble is predisposed to a subsequent attack and must therefore adopt suitable measures for protection against such an attack.

It would appear, however, that there is a condition in which we are justified in speaking of the disease as having become quiescent. Encapsulation of a tuberculous deposit may take place, and it has been shown that such deposits may continue to contain the active tuberculous virus—*i.e.*, the bacilli. Caseous material, too, may become infiltrated with calcareous salts, and these deposits very frequently possess the active tuberculous virus.

In early cases of joint tuberculosis we often succeed by treatment in getting excellent results with a minimum amount of damage to the tissues. If the case is seen early and treatment by prolonged rest is carefully carried out for a long period, we may succeed in effecting a cure without any deformity or impairment of the joint function. In such cases we may suppose that the infective material has been entirely eradicated from the tissues, and that there is not the same danger of recurrence because a minimum amount of fibrous tissue has been formed.

The conditions under which the bacillus of tubercle thrives are difficult

to reproduce in the laboratory, and while, under certain circumstances, the tissues of the body may supply a suitable nidus for its growth, yet it would appear that the necessary conditions may be upset and the virus cease to flourish. Comparatively speaking, the human tissues do not form a suitable environment for the development of tubercle. The susceptibility of various animals to tuberculosis varies greatly. Thus the guinea-pig falls an easy prey to a minute dosage, while, on the other hand, the dog is not easily inoculated. Experimental evidence also goes to show that in an animal, such as the dog, which is not easily affected, tuberculosis tends to be restricted to local manifestations and does not tend to become disseminated generally. In man this is also the case and by far the most frequent manifestations of tuberculosis are in localized areas, while general miliary tuberculosis is comparatively rare. Cheyne found remains of tuberculous material in the tissue about a joint in which fibrous ankylosis had taken place, and he alludes to the danger of breaking down such a joint forcibly lest the disease be lighted up again. It is a familiar circumstance that fresh disease may light up after manipulation of a joint which has been the seat of old-standing disease.

The constitutional and local conditions which affect the growth and development of tubercle in the tissues, and hence the prognosis in existing disease, may be referred to in this connection. The "constitution of the patient" may predispose to tuberculosis. We have already considered heredity, and we may note that children of tuberculous parents may contract tuberculosis because of some inherited type of development which results in a diminished power of resistance, but it is obvious that the children of such parents may contract the disease from an infected parent or may fall victims to it because they are living under conditions similar to those of the parents, and these home surroundings may be responsible for inducing disease quite apart from hereditary taint. Such conditions as bad food, ill ventilation, exposure to cold and wet, etc., may be shared alike by the parents and children, who may also share in the development of tuberculosis. Where such an environment exists, the prognosis in tuberculous disease is undoubtedly not so good as under more favorable surroundings. Climatic conditions are also factors affecting the spread of tuberculosis. There are certain diseases which appear to predispose to tuberculosis, or in some cases to aggravate the tuberculous condition which may be present. Thus, measles may be followed by strumous lymph nodes in the neck, or tuberculous joint disease; so, too, may scarlet fever, whooping cough, etc. Of the local conditions affecting the occurrence of tuberculous joint disease we have referred to injury; this may also affect the course of an existing disease. Cheyne holds that the virulence of the bacillus itself is a factor, as the virulence varies in different cases; no doubt, too, the dosage has a marked influence in many cases. All these factors necessarily affect the prognosis. Lastly, in this connection the occurrence of sepsis has undoubtedly a marked effect on the prog-

ress of the disease. This fact is perhaps most clearly demonstrated if we compare the way in which a tuberculous abscess disappears when we succeed in getting it to heal by first intention after opening it and evacuating its contents and finally stitching it up without drainage under efficient aseptic conditions, with the condition of affairs which supervenes when mixed infection occurs; in the latter case destructive processes rapidly manifest themselves and an entirely different complexion is given to the case, necessitating a much more serious outlook.

The Treatment of Tuberculous Joint Disease.—Treatment may be considered under two headings: first, the constitutional, and, second, the local measures which may be indicated.

Constitutional Measures.—Tuberculous patients must be placed under proper hygenic surroundings. It must be remembered that spontaneous cure is possible in many cases of joint tuberculosis, and that certain conditions favor the production of that spontaneous cure, while other conditions militate against it. Further, while we are adopting definite measures for the local treatment of the trouble, we must also secure for the patient careful attention to his general state of nutrition, for the latter reacts most markedly on the course and progress of the local disease. These indications have been stated to be fulfilled by placing the patient in surroundings most favorable for the maintenance of a maximum degree of nutrition, and by taking such measures as, in a local or general way, influence the tuberculous processes. (Osler.) The principle involved in the *open-air treatment of pulmonary tuberculosis* is important here, and there can be no doubt of the importance of securing, if possible, similar conditions in the treatment of joint tuberculosis. The great advantage of this treatment is annually demonstrated in Toronto, where the Hospital for Sick Children (one hundred and fifty beds) transfers all its patients to summer quarters (the Lakeside Home) every year. They are provided there with a hospital at Toronto Island, on the shore of Lake Ontario. The summer hospital is provided with extensive veranda space, so that the patients may enjoy the maximum amount of sunshine, may sleep in their cots in the open air, and thus may remain constantly in an atmosphere which is pure, and of a fairly equable temperature. The beneficial effects of these surroundings are most obvious; children suffering from joint tuberculosis in all stages are markedly benefited, and it is not unusual to watch with anxiety a serious case of tuberculous arthritis toward the end of the winter in the hospital in the city, in the hope of tiding the patient over the necessary time until he is able to be transferred to the Lakeside Home, where one has every confidence that he will be benefited. The question of climate is to be discussed from the same standpoint. This subject cannot be treated here at any great length, but one may say that the main objects to be attained in any climate are those which we have referred to, namely, to see that the atmosphere is pure;

and for that reason cities and towns are to be avoided, if possible, and country districts preferred. Sudden changes in temperature are baneful and must be avoided, and the maximum amount of sunshine should be secured. These are the considerations which should guide us in the choice of a suitable climate. Where it is impossible to send the patient away from home, then an effort should be made to secure the necessary conditions in the home or in the hospital. Ventilation of the room or the hospital ward must be efficient. In cold climates patients should be taught that pure air in a room is much more important than warm air, and they should learn that it is possible to keep the body warm in a cold atmosphere by suitable clothing; the bedroom window should be open at night and the patient should live as much as possible in the open air.

Good, nourishing food is another essential. This must be provided of the character and amount which can be assimilated by the patient. The appetite may be stimulated by the administration of a bitter tonic. Bidder's suggestion that the foods should be rich in soda and fat, and excess of vegetables avoided, may be found worthy of adoption.

The *administration of certain drugs* may be of service. Cod-liver oil is of value in tuberculous arthritis; in pulmonary tuberculosis its action is said to be less certain. A teaspoonful thrice daily after meals should be given. The hypophosphites are useful tonics and may be given with advantage. The combination of the syrup of the iodide of iron with cod-liver oil has long been recognized as of value. Arsenic is also of service; there is no general tonic more satisfactory in cases of tuberculosis of all kinds than Fowler's solution. (Osler.) The value of tuberculin as a specific form of treatment for joint affections will be discussed more in detail presently (page 592); if some of the more recent investigations are as successful in establishing facts which would show beneficial results as they appear to promise, then we may hope that in the future this treatment will be employed with great advantage.

The nutrition of the body is improved by *exercise*, and hence we must bear in mind the necessity of combining properly regulated exercise with our treatment where that is at all possible.

Local Treatment.—*Rest* of the diseased articulation is a most essential part of the treatment in tuberculous joint disease. This is to be accomplished by suitable splinting. The form of splint will vary with the particular joint affected, and, again, with the acuteness of the inflammatory processes which may manifest themselves during the course of the disease. Thus, if we are treating hip-joint disease in the early stage, and we find the patient to be suffering from pain and that the temperature is elevated, it is best to confine that patient to bed while the acute symptoms are in evidence. On the other hand, when the inflammatory symptoms have subsided and the disease has become quiescent, we must permit the patient to get about and to take exercise. It is ob-

vious that some special form of retentive apparatus which may be efficient while the patient is in bed may be of little value while the patient is going about; hence it may be necessary to employ different methods of splinting in the two cases. Certain forms of splint which we shall describe later are of service both as bed splints and as splints with which the patient goes about.

An important principle to have in mind when we thus secure a limb at rest is to correct at the same time any faulty position of the limb which may have been assumed. In view of the fact that tuberculous joints may become stiff or even ankylosed as the disease progresses, it is wise to see that rest for the articulation is secured with the limb in such an attitude that should stiffness occur the limb will be fixed in the position which will subsequently be most serviceable. Thus the ankle should be splinted so that the foot is at a right angle with the leg. Flexion at the hip or knee must be corrected; the elbow should be flexed and the forearm placed in a position half way between pronation and supination, etc.

Many different materials have been used for splinting purposes. Plaster of Paris is of great service and may be used extensively in the treatment of tuberculous arthritis. The knee or ankle may thus be most efficiently splinted by encasing it in plaster. So, too, the hip may be fixed by the application of a plaster spica (see Fig. 269). The joints of the upper extremity may also be secured by means of plaster bandaging. Special splints are devised for different articulations and may be made of leather, poroplastic material, steel, etc. These will be described when we come to deal with the individual joints.

The effect of rest is to permit a subsidence of the inflammation. While in the broadest sense we must consider inflammation as the attempt on the part of nature to repair injured or diseased tissues, yet it is obvious that rest is necessary in order to make sure that inflammation shall not lead to destructive processes. The effect of unrest is to maintain and increase the inflammatory reaction, and we know that such a process may have a baneful effect. The exudate may be excessive and the wandering cells may themselves become destroyed. We have already seen that the tuberculous process readily invades tissue which has become the seat of a chronic inflammation and in which there has been the development of granulation tissue or even of fibrous tissue (*vide* page 574); and so it becomes necessary to keep these parts at rest and allow the inflammation to subside. Pain is an excellent splint and it is by means of this symptom that nature demands rest for an injured and inflamed part, but the promptings of nature are frequently not sufficiently urgent in this regard in tuberculous disease, and therefore we must the more be on our guard to see that rest is provided.

Traction.—This is merely a means of securing rest and is a most valuable one. The usual way of securing traction in the lower extremity is by means

of the weight-and-pulley apparatus such as will be illustrated in describing the methods employed in dealing with the individual joints. The object of employing traction is to remove the cause of unrest, which is produced by the tonic contraction of the muscles about the inflamed joint. When these muscles contract they press together the inflamed articular surfaces and thus cause pain and maintain the inflammation. Great relief is experienced, by patients suffering pain in a tuberculous joint, when traction is applied. The amount of weight need not be great; the constant steady traction of a small weight will soon tire out powerful muscles and overcome the pressure exercised by their contraction upon the joint surfaces. Traction is, of course, of most value in disease of bone or cartilage and is not so notably effective in synovial disease, although it has a beneficial influence here too. Traction, also, is of service in correcting the faulty attitude of the limb, as will be illustrated more particularly in treatment of the hip and knee.

Counter-irritation.—The action of a counter-irritant is to bring about a reflex contraction of the vessels in the inflamed tissues. Thus a blister may be applied over an inflamed knee with good effect; the superficial vessels are dilated visibly, producing a reddening of the skin, and the deeper vessels are contracted, and thus pain is relieved. One finds in tuberculous arthritis that such measures are seldom called for, as the inflammation subsides with rest and extension quite satisfactorily.

The actual cautery has been used for counter-irritation with good effect in tuberculous disease, more particularly in the hip, the shoulder, and the spine.

Scott's dressing, composed of compound mercurial ointment spread on chamois leather, is cut in narrow strips and applied firmly, say, over the knee joint; one strip being made to overlap the other, as is done in strapping a joint in the ordinary way. This dressing, which has long been used in chronic inflammatory processes will be found of value in tuberculous arthritis. It combines the effect of a counter-irritant with that of firm pressure.

Injection of Iodoform Emulsion.—This consists of the injection of iodoform emulsion in glycerin directly into the joint cavity. The method of its employment may here be described, as it has been so widely used. It is well to remember that the preparation is not powerfully antiseptic, and in fact the iodoform may not be sterile; consequently great care must be taken to insure that the material shall be sterile before it is used. The method of preparing it recommended by Cheyne is as follows: The iodoform used for the emulsion should be allowed to stand submerged in a five-per-cent watery solution of carbolic acid for at least forty-eight hours, the bottle being frequently shaken so as to insure the free access of the acid to the powder. Instead of using glycerin alone, it is well to add one two-thousandth part of perchloride of mercury to it. The iodoform is strained from the carbolic acid, and is mixed with the glycerin in the proportion of ten per cent. The emulsion

should be put in a sterilized bottle and allowed to stand for another twenty-four hours before it is used.

The method of injection consists in taking a syringe of suitable size, plunging the needle directly into the joint cavity, and injecting the emulsion. The total quantity used should be accurately measured because there may be some danger of causing iodoform-poisoning as well as toxic effects from the glycerin. In children, from one to four drachms may be safely used, and in adults as much as half an ounce. Part of the material may be advantageously injected into the thickened synovial membrane at several points as well as into the joint cavity. After the injection, the joint swells up in consequence of effusion into it, but this swelling goes down in two or three days. The injection is repeated once a week and persevered with until the joint has sufficiently recovered, or until it becomes evident that the treatment is no longer doing any good. The injection of iodoform emulsion into tuberculous joint cavities is of doubtful value and by some is held to be positively injurious. In the Hospital for Sick Children, Toronto, it was given a fair trial, but is now no longer used.

Operative Measures.—The treatment of joint tuberculosis by operative means constitutes a method of dealing with these cases which occasionally becomes necessary. Definitely localized tuberculous deposits in bone may be excised. Now and then it may be possible to remove such a focus in the articular extremity of a bone without opening the joint cavity. Excision of a tuberculous joint is sometimes called for, or, short of that, the joint may be opened and all infected tissue carefully dissected away, as in the operation called "erasion" or "arthrectomy." Amputation is rarely called for, but may become necessary where it is hopeless to attempt to save the limb and where life is endangered. Where septic sinuses exist, these must be dealt with, and tuberculous abscesses usually demand operative interference. The indications for operation and the various methods suggested will be discussed fully in connection with the various joints.

Local Hyperæmia as a Therapeutic Agent.—A method of treatment known as "the Bier treatment," because introduced by Professor Bier, of the University of Bonn, is one in which hyperæmia is utilized as a therapeutic agent; this is mechanically induced by stasis. The technique of this procedure may be described as follows: A so-called "cured" or elastic woven rubber bandage is applied around the limb above the affected joint; the bandage must not be restricted to a limited area, but must be spread over a considerable portion of the limb, the reason being that it is difficult to attain the desired degree of hyperæmia if the various turns of the bandage cover one another and thus encircle the limb over a restricted segment only. The bandage must be applied firmly enough to produce a vigorous stasis hyperæmia. The subcutaneous veins distal to the bandaged part will swell markedly, the skin becomes bluish-red, and at the end of about an hour a slight prickling sensation will be

experienced by the patient. The portion of the limb distal to the affected joint is not bandaged. It is not necessary that the bandage should be applied close above the affected joint; thus, in tuberculosis of the wrist or of the ankle joint, the bandage may be applied around the upper arm or the thigh respectively if for any reason one would rather not apply it immediately above the joint. The stasis induced should never produce pain. It would appear that in some cases pain may be produced, and, if so, then the method of treatment should be abandoned, as it is likely to do harm. One must remember, however, that pain may be caused by faulty technique; under no circumstances, therefore, must the patient be allowed to suffer pain from the treatment. Another precaution to bear in mind, and one, too, which aids us in determining the degree of hyperæmia to be attained, is that the temperature of the limb distal to the bandage must not be rendered cold by the process. The limb must not become colder to the touch than its fellow of the opposite side. On the contrary, it is often possible to induce an elevation of temperature in the affected limb; in fact, it is considered most favorable if the temperature of the affected joint thus rises during the treatment. The bandage must not be applied for a longer period than one hour daily. The duration of treatment is regulated by the progress made by the patient; it is continued until pain and swelling have disappeared and until free movement of the joint is attained—until, in fact, a cure is effected. Most of these cases of tuberculous arthritis require treatment that extends over some months; it is not unusual to continue it for a year or even longer. Frequent intermissions of treatment of, say, eight days are found advisable. If a tuberculous abscess exists when the patient is put under treatment, it is opened and the pus evacuated, and from one to three days must elapse before stasis hyperæmia is instituted. Should such an abscess develop during treatment it is evacuated and the treatment postponed for a few days. Should the tuberculous abscess be of large size, it is well to wait until the wound has healed before producing the hyperæmia. Sinuses frequently close under the treatment; care must be taken to remove sequestra of bone, which may be the cause of the persistence of sinuses. Tuberculous ulcers, too, it is claimed, improve under treatment. The joints are not kept at rest during treatment; on the contrary, the patients are encouraged to use the affected joints as long as there is no pain. While pain persists, however, it is prudent to keep the joints at rest. At the same time it should be stated that some degree of caution should be used so that the patients may not strain the affected joints by heavy work; walking, in affections of the lower extremity, is often possible without discomfort, and then should be encouraged in moderation; care should be taken to prevent the production of flat-foot in diseased tarsus. Exercise is not permitted while there exist tuberculous ulcers, abscesses, or sinuses. By such means it is claimed that this form of treatment results in the preservation of functionally useful joints, while other con-

servative forms of treatment in which rest is essential bring about a cure with the joint stiff and functionally useless. In a certain proportion of cases it would appear that the Bier treatment is unsuitable, and, when improvement does not take place after a fair trial, then this method of treatment should be abandoned. It is also useless to attempt this treatment where cases come under observation with such a degree of deformity that resection is necessary. Further, the Bier treatment should not be attempted in the presence of very large tuberculous abscesses, or where there is hydrops articuli.

It is claimed that by the Bier treatment certain very definite results are attained which have a beneficent effect upon the progress of the case. In the first place, the analgesic effect is most striking and of importance as a feature of the clinical course, affording much relief to the patient. A further effect of the hyperæmia is rapidly to diminish and abolish pain. Within an hour this result is often attained. The abolition of pain, in turn, prevents the reflex contraction of muscles, and the joint becomes mobile and is no longer fixed. Deformity due to faulty position and ankylosis is thus prevented.

Hyperæmia, too, is said to have a bactericidal effect. This is explained in a variety of ways: (*a*) It may be accounted for by the increased number of leucocytes leading to a destruction of the bacteria through their agency; (*b*) the products of the metabolism of the bacteria may be retained, and thus self-destruction is brought about (a sort of tuberculin effect); (*c*) it may be through a concentration of the bactericidal power of the blood at the seat of the infection; (*d*) the blood may be more actively bactericidal because of its increased alkalinity; (*e*) lastly, it may be that Wright's theory as to the increase of the opsonic index may be explanatory of the effects produced upon the bactericidal quality of the blood under such conditions. There is, too, an absorptive effect produced by hyperæmia. This is most noticeable in the active hyperæmia which is produced by hot air; this will rapidly remove the œdema, which is temporarily induced by passive hyperæmia in the Bier treatment of tuberculous joints; further, not only does the œdema subside after the bandaging treatment, but absorption occurs, so that the swelling which was present before treatment was initiated disappears. Bier would have us believe that there is a solvent action produced, so that the greater part of the diseased granulations and the adhesions in the stiff joint are converted into substances soluble in water and are then absorbed by the blood. Lastly, a nutritive effect is produced by hyperæmia. Regeneration of tissue is promoted by both active and passive hyperæmia. These regenerative effects can be observed by comparing a skiagraph taken after treatment with one taken before treatment was begun. In the latter the outlines of the bones are indefinite and indistinct and their shadows light, while in the former these outlines are much improved; they become distinct and definite and the shadows more dense.

The Tuberculin Treatment.—The treatment of tuberculous arthritis by means

of Wright's opsonic index and Koch's tuberculin promises to constitute an important addition to scientific surgery. The basis upon which the treatment by Wright's method is carried out must be referred to in order that the objects aimed at in the treatment may be understood. Wright and Douglas, of St. Mary's Hospital, London, studied the phenomenon of phagocytosis in 1903. They found that leucocytes separated from the blood stream and suspended in a neutral medium were incapable of any phagocytic action when mixed with an emulsion of staphylococci, but the addition of blood plasma or blood serum had the effect of immediately inducing phagocytosis. These results showed that the leucocyte itself was incapable of phagocytosis, except in the presence of blood serum or blood plasma. By special methods of experiment they determined that the blood plasma contained an element which acted upon the micro-organisms and so affected them that the leucocytes were now able to destroy them by phagocytosis. The substance in the plasma which thus prepares the micro-organism for the action of the leucocyte was called an "opsonin" (from *opsono,* I cater for, I prepare victuals for). The opsonins are supposed to be carried in the lymph stream to the bacteria which have invaded the tissues, and there the opsonins chemically combine with the bacteria. It is only after the bacteria have combined with the opsonins that the leucocyte is capable of carrying on its rôle of activity in the phenomena of phagocytosis. The leucocyte does not appear, therefore, to assume the active rôle in phagocytosis that had previously been assigned to it. Urwick takes an advanced view when he states that "their use may be compared to the use of culture media in bactericidal experiments to estimate the number of bacteria which have been destroyed."

If normal serum is heated to 60° C. for ten minutes the opsonins are completely destroyed. It has been shown that the opsonins are distinct from bacteriolysins, agglutinins, and antitoxins. The opsonins also have a high degree of specificity; thus the blood of a person may contain half the quantity of opsonins necessary to combat effectively a tuberculous affection, *e.g.*, a tuberculous cystitis, and yet contain a normal amount of opsonins that have to do with an invasion of staphylococci such as causes furunculosis. (Ross.) It would appear that the phagocytic action of the leucocyte is a constant factor. Thus leucocytes separated from the plasma of an immunized individual would show the same degree of phagocytic action when mixed with an emulsion of staphylococci as would the leucocytes similarly separated from the blood of a normal individual. But should one add the serum of an immunized individual to the mixture of leucocytes and staphylococci, then the amount of phagocytosis would be one-half greater than that which would take place were the serum of a normal patient substituted for that of the serum of an immunized patient. So far as we can tell at present, plasma has nothing to do with the "quality" of the leucocyte. (Ross.) It appears that the degree of phagocytic activity of the

leucocyte is in direct proportion to the amount of opsonins present in the plasma.

The application of these facts to the practical treatment of tuberculous affections is brought about by determining the opsonic power of the patient's blood, and then using therapeutic means to increase that power and thus augment the bactericidal quality of the blood.

The technique employed by Wright is as follows: We must first of all obtain equal quantities of—

(*a*) The patient's serum.

(*b*) Blood corpuscles washed in a solution of one-half per cent sodium citrate in normal salt solution.

(*c*) An emulsion of tubercle bacilli.

A drop or two of blood from the patient will be sufficient to give us the necessary quantity of serum. The source of the corpuscles may or may not be from the patient, they may be drawn from a healthy person; the result will be the same, for reasons which we have already explained. Equal quantities of (*a*), (*b*), and (*c*) are drawn up into a capillary pipette; this is sealed and placed in an incubator for twenty minutes at 37° C.; films are made of the mixture, and these are stained in the ordinary way for tubercle bacilli. The average number of tubercle bacilli ingested by each polynuclear white corpuscle is then calculated by counting a definite series of these, and the figure thus obtained gives us an index of the phagocytic activity of the leucocytes. In order to institute a standard for comparison we must carry out another experiment, substituting, however, the serum of a normal individual for that obtained from the patient. Thus, we obtain what is called the "phagocytic index" of the patient, and we compare it with the "normal phagocytic index" of a normal individual. For example, the average number of bacilli found in the tuberculous patient under observation may be 2 (phagocytic index) and that in the normal individual 4 (normal phagocytic index); the actual ratio being 2 : 4, or 0.5 : 1.0. We would then speak of 1.0 as the normal "opsonic index" and 0.5 as the "opsonic index" of the tuberculous patient.

It is necessary that the standard serum and the serum from the patient must be withdrawn within a few hours of the same time, because the opsonic power of serum after it has been withdrawn from the body gradually diminishes.

In localized infections the opsonic index is found to be below normal, but in systemic infections the opsonic index is a variable factor—at one time low, at another high. Thus in pulmonary tuberculosis the opsonic index has been frequently observed, as, say, 1.6, and a few days later, 0.5. On the other hand, take such a localized affection as tuberculous lymph nodes in the neck, or a tuberculous hip joint, and the opsonic index will be low continuously.

The practical application of these facts to the treatment of tuberculous

arthritis consists in employing measures to increase the opsonic index and maintain it at a high level. so as thus to augment the bactericidal quality of the blood by increasing the number of opsonins in the serum. The way in which Wright attains this end is by inoculating the patient with dead micro-organisms of the same species as that maintaining the disease. The vaccine used in tuberculosis is Tuberculin T. R., which is made from the finely triturated bodies of tubercle bacilli.

The effects produced by the inoculation of a bacterial vaccine into the tissues has been described by Wright in the following terms:

1st. Upon the inoculation of the vaccine there supervenes a period of intoxication which is characterized by a decline in the antibacterial power of the blood. This "negative phase" is more or less accentuated or prolonged according as a larger or smaller dose of the vaccine is inoculated. In the former case the "negative phase" may disclose itself to clinical observation by a temperature reaction and constitutional disturbance. In the latter case the "negative phase" may be quite unaccompanied by clinical symptoms.

2d. Upon the "negative phase" there follows a "positive phase." This phase, whose characteristic feature is an increase in the antibacterial power of the blood, corresponds to a period of increased resistance. There is associated in many cases with the climax of the "positive phase" a sense of increased physical vigor and a very profound feeling of well-being.

3d. After the negative phase (which Wright has called the "ebb and flow of the tide of immunity") the blood may be maintained for a variable period (after tubercle inoculation, occasionally for as long as a month) at a somewhat higher level of antibacterial power than before inoculation. Or—and this, in connection with inoculation with tubercle vaccine, is a more constant event—the antibacterial power may over and over again fall back, after ten days or a fortnight, to the level at which it stood anteriorly to inoculation.

A study of these results suggests a plausible theory which has been put forward to explain the fact that in localized tuberculous affections the opsonic index is continuously low, while in general tuberculosis the opsonic index shows great fluctuations. In the generalized affection we find that the tuberculous patient is constantly inoculating himself; there are from time to time a greater absorption of toxins and a greater stimulus to the production of protective substances in the blood. This "auto-inoculation" in its immediate effect produces a negative phase, as in the inoculation artificially produced, but it too has the positive phase succeeding the negative and resulting in the production of a high opsonic index. Thus in these cases of systemic tuberculous affections there is a great deal of fluctuation in the opsonic power of the blood due to the conveyance of bacterial elements into the blood in irregularly interspaced doses. On the other hand, in localized affections the opsonic power is constantly low, and this is accounted for by assuming that a low opsonic index

existed prior to the tuberculous infection; then, because of the fact that the lesion is localized, there is not the same conveyance of bacterial elements into the blood that there is in the generalized affection, and hence auto-inoculation does not take place, and the opsonic index remains continuously low. Wright utilizes this theory to explain why it is that many localized tuberculous affections do not tend to get well, but are of almost indefinite duration, as is the case, *e.g.*, in lupus.

These considerations and the conclusions therefrom may otherwise be expressed by stating that an increased opsonic power is to be expected in those cases in which there has been an active response, on the part of the machinery of immunization, to the stimulus of infection; and a decreased opsonic power is to be expected in individuals in whom there is an inherent deficiency in opsonic power or in whom the machinery is becoming exhausted. It is not unusual to find the opsonic power high in acute affections, even in localized disease. The following table from Urwick's statistics shows the low index in tuberculous joint disease. It will be noted that the acute cases Nos. 1 and 2 showed a high opsonic power:

No.	Age.	Disease.	Opsonic Power.
1.	5	Acute tuberculous disease of the hip, duration 1 month	1.20
2.	8	Acute tuberculous knee	1.30
3.	18	Tuberculous caries of the spine with abscesses for many years	.80
4.	13	Chronic tuberculous disease of the hip joint, duration 13 months	.30
5.	8	Psoas abscess, duration 18 months	.40
6.	28	Psoas abscess, duration 2 years	.80
7.	8	Chronic tuberculous disease of the hip joint, duration 4 years	.80
8.	68	Tuberculous disease of the elbow joint, duration 6 months	.50
9.	4	Acute tuberculous disease of the ankle joint	.80

The explanation of the high opsonic index in certain of the acute cases of localized affections is doubtless found in the greater absorption of toxins which occurs in such cases, this acting as a stimulus to the production of opsonins in the blood. In the acute case, No. 9, the machinery of immunization was probably overtaxed and exhausted.

An important observation must be made regarding the cumulative effect produced by the inoculation of bacterial vaccines. Cumulation in the direction of the negative phase is always produced; but in inoculation in tuberculosis it is difficult, if not impossible, to get cumulation in the direction of the positive phase. (Wright.) For this reason Wright is content to treat each inoculation in tuberculosis as an independent event. In view of the fact that cumulation in the direction of the negative phase is a constant factor, it is essential to have frequent examinations made of the patient's opsonic power during inoculation treatment. Obviously, serious harm may be done if this caution is not observed. For example, the negative phase after tuberculin may last ten days and from clinical symptoms and signs we get no evidence of this. If in such

a case a second inoculation is given during the negative phase, evil, and not good, will result. In every case, therefore, examine the blood before inoculation. (Urwick.)

We are dealing in this article with the treatment of joint tuberculosis, *i.e.*, localized tuberculous affections. Wright's dictum regarding such is that in the treatment of localized affections it is necessary to raise the opsonic power of the blood and to keep it at a high level, and to bring the antibacterial lymph into contact with the organisms in the local lesion. The principles underlying this treatment have been outlined by him as follows:

1st. The tuberculo-opsonic power of the blood in these cases appears to be uniformly inferior to that of the normal blood.

2d. The immunizing stimuli which are required for raising the opsonic power and for maintaining it at a high level here make default.

3d. The tubercle bacilli are cultivating themselves in the focus of infection under conditions which are much more favorable to their growth than those which obtain in the case of the circulating blood.

4th. An increase of the opsonic power of the blood can be achieved and maintained by the inoculation of a series of appropriately adjusted and interspaced doses of tubercle bacilli.

5th. We have at our disposal methods by which we may increase the lymph flow through the focus or foci of infection in such manner as to bring the antibacterial element of the blood into application upon the invading bacteria.

The material used for inoculation is Tuberculin T. R., and certain precautions must be employed in regulating the dose. Wright advises that the dose to begin with should be 0.001 mg. The dose must be small because of the danger of producing a prolonged negative phase which would be the result were too much tuberculin given. The dose may be increased to, say, $\frac{1}{400}$ mg. These doses refer to the weight in milligrammes of the tubercle powder. The machinery of immunization may be brought into action by a very small dose, and this may be very easily overtaxed, so that one must use the smallest dose that will produce a satisfactory response. (Wright.) In the case of an inoculation which is successful, the opsonic power is raised and is maintained at a higher level. The ultimate result depends on the correct interspacing of appropriate doses of vaccine. The dose is to be repeated when the effect of the first inoculation is passing off, as indicated in a decline of the opsonic index; and the dose is to be increased only when the previous inoculation has failed to evoke a satisfactory response. The effect of a second inoculation given when the positive phase is at its height will be to raise the opsonic power to a still higher level, but the effect of a second inoculation given during the negative phase will be to reduce still further the opsonic power, already reduced by the first inoculation. In both cases the effect of the inoculation may be cumulative; in the former case it is always so in the direction of in-

creased resistance, and in the latter in the direction of diminished resistance to bacterial invasion. With each dose the negative phase should become less pronounced; if it becomes more pronounced the dose is too large. The positive phase following inoculation may last a long time; thus a positive phase lasting two months has followed the inoculation of $\frac{1}{800}$ mg. (Urwick.) To repeat too soon only cuts short the positive phase and induces an accentuated negative phase.

In addition to the means here employed for raising the opsonic power of the blood, it is possible to utilize methods which send a stream of the antibacterial lymph through the focus of disease. Wright instances the empirical methods in vogue which apparently acted in this way in producing their beneficent effects: the old-fashioned poultice, Bier's method of obstructing the circulation, the use of rubefacients and iodine, the *x*-rays, radium, or radiant heat. All these, according to Wright, had the effect indicated. They may be used intelligently along with the inoculation treatment. In fact, if not used intelligently they may do harm, and not good. The following considerations suggested by Wright illustrate the principles which he would have us consider in employing such adjuncts to the inoculation treatment:

(*a*) Douching a bacterial nidus with lymph of low antibacterial properties is not unassociated with risk (*e.g.*, general infection might follow).

(*b*) Douching a bacterial nidus with lymph is best after raising its antibacterial properties by auto- or artificial inoculation.

(*c*) An ampler lymph stream may be attained after decalcifying agents (*e.g.*, citric acid) have reduced the coagulability of the blood.

(*d*) The injection of decalcifying agents dissolved in concentrated sugar or salt solution into discharging sinuses may possibly be found useful in increasing the irrigation of such sinuses by lymph.

(*e*) If the Finsen light acts by determining lymph to the seat of infection, then this result might be accomplished by cheaper and less laborious methods. Wright suggests the use of hot sterilized sand for the purpose, this being considered a very inexpensive and convenient method of determining a blood stream to any region on the surface of the body. For the sterilization of sand Wright gives the following instructions: Place the sand in a saucepan over the fire, having previously stirred in a number of small pieces of white paper. Continue the stirring until, with the attainment of a temperature of 200° C., the pieces of paper have all turned brown.

If we are to accept the theories promulgated by Wright, we have an explanation of the beneficial effects which may follow operation for tuberculous disease, even in those cases in which the surgeon has only partially succeeded in removing the focus of disease. This phase of the question is dealt with by Wright when he says, regarding operations, that "they may be followed by the whole train of events which we have learned to associate with the inoculation

of a bacterial vaccine." So, too, he claims that exercise may be an active agent in connection with the production of immunity, and massage may produce effects similar to that of inoculation.

II. TUBERCULOSIS OF INDIVIDUAL BONES AND JOINTS.

Tuberculous Disease of the Bones of the Skull.—*The mastoid process of the temporal bone* is more frequently the site of tuberculous disease than any other bone of the skull. Its appearance there is associated with disease of the middle ear. Pyogenic infection is prone to occur, and then serious complications may result from extension of the septic processes to the lateral sinus or the meninges of the brain; abscess in the brain may have its origin in such a process.

The subject of tuberculous invasion of the mastoid does not require extended reference here, as it will be dealt with in the article relating to surgical diseases of the ear.

The flat bones of the skull are occasionally, though rarely, the seat of tuberculous disease, and a number of cases are now on record. The bones most frequently affected are those of the cranial vault, the frontal, the parietals, and the occipital. Headache is complained of, and there is local swelling with tenderness on pressure over the affected area. Sooner or later fluctuation is found, as the result of the development of a chronic abscess.

These bones are most commonly involved in young adults, and, as a rule, there is, at the same time, tuberculous disease in other bones in the body. Thus in a case, which was reported by the author, and in which there was perforation of the parietal bone by tuberculous disease, there were six tuberculous lesions in other parts of the skeleton in addition to the one in the skull.

The disease may begin as a periostitis that soon develops into a superficial caries, but it is apparently more common for it to originate in the diploë. Caseation and suppuration result, or small sequestra may be formed. These are usually about the size of a pea or bean. Perforation of the bone commonly occurs as the result of a necrotic process extending through the entire thickness of the bone. The inner table of the bone may be extensively affected.

When an abscess forms it may come to the surface externally, or it may extend beneath the dura mater, separating it from the bone. Such cases have, in their progress, been associated with symptoms indicative of pressure upon the brain. When a perforation exists the pulsation of the brain may be transmitted to the pus of the abscess. If the abscess opens, and mixed infection occurs, then a septic condition will be induced, with continued suppuration. A probe introduced into such a sinus will impinge upon bare bone in a condition of caries, or it may pass through a perforated bone into tuberculous material which has formed on the surface of the dura mater.

There may be a single focus or there may be several foci in one bone, or, again, several bones may be the seat of disease.

The disease with which this condition is apt to be confused is syphilis. The history of the development of the disease may aid us, but it is sometimes impossible to establish a diagnosis with certainty until an abscess forms or operation is undertaken, when the microscopic finding will demonstrate the true nature of the disease.

The treatment to be adopted in these conditions depends upon the stage of the disease at which the individual case comes under observation. If an abscess has formed and is not yet open, one should incise it and evacuate its contents, remove the diseased bone by curette or chisel, or, if necessary, by trephine, and then endeavor to get the wound to heal by primary union. On the other hand, if septic conditions exist, one must establish efficient drainage after removal of sequestra and all tuberculous tissue. It is usually very easy to separate the sequestra, and in that particular the tuberculous sequestrum of the skull differs from the syphilitic sequestrum, as the latter is usually firmly held in position by the condensed bone which surrounds it.

The outlook in these cases is not at all favorable; the disease is usually part of an extensive and serious involvement of bone in different parts of the skeleton. Even should recovery eventually take place these patients do not improve rapidly, but, as a rule, are subject to frequent recurrences; and, in all probability, several operations will be required before the disease is finally eradicated. A noticeable feature of these cases is the somewhat remarkable manner in which, after recovery has taken place, the gaps in the skull fill in with new bone formation.

The bones of the face are more frequently the seat of tuberculous disease than are the flat bones of the vault of the cranium. The superior maxilla near the orbital margin is occasionally the seat of a tuberculous periostitis that results in caries of the bone and the formation of a chronic abscess. Similar trouble has developed in the malar and in the nasal bones. The author has had under observation a lad eight years of age, who, while suffering from tuberculosis of the tarsus, developed caries of the malar bone.

The lower jaw has been the seat of tuberculous disease. It usually manifests itself near the angle, where a chronic swelling and subsequently a tuberculous abscess may develop. At least one case is on record where spontaneous fracture of the jaw occurred at the seat of a tuberculous lesion.

The treatment of these manifestations of tuberculosis in the facial bones consists in operations carried out for the removal of the disease; for this purpose the methods advocated for the removal of similar foci elsewhere and for the treatment of chronic abscess and fistulæ may be employed. (*Vide* p. 677.)

Tuberculous Disease of the Temporo-Maxillary Joint.—Tuberculous disease

of this articulation is not of common occurrence. Marsh records two cases in which a tuberculous periostitis of the external aspect of the ascending ramus of the jaw made its way into the temporo-maxillary joint. In one of these there had formed a large collection of pus which extended from the angle of the jaw to the zygoma. When this was opened the surface of the jaw was found to be bare, and a probe passed readily into the interior of the joint. The patient was a boy ten years of age; he ultimately recovered, but the movement of the jaw on that side was much impaired.

Marsh is authority for the statement that tuberculous disease of this joint may occur secondarily to middle-ear disease; suppuration finding its way from the tympanum through the fissure of Glaser into the joint.

The use of counter-irritants may be of service in the early stage of the disease. When abscesses form, they should be opened and treated by appropriate methods already described.

Ankylosis very commonly occurs as the result of disease in this articulation, and the surgeon is called upon to operate for its relief. Under such circumstances resection of the joint becomes necessary.

Tuberculous Disease of the Clavicle and the Scapula.—These bones are rarely affected with tuberculous disease. According to Cheyne the clavicle is most frequently affected at the acromial end, and most commonly the disease is an extension from the acromion process of the scapula. Disease of the sternal end and of the sterno-clavicular joint has also been recorded.

The disease may manifest itself as a chronic periostitis or as an osteomyelitis; if the latter is present there develops a condition similar to that described as "spina ventosa" in the foot or hand.

The glenoid cavity and the neck of the scapula may, as will be seen farther on, be involved in a tuberculous arthritis of the shoulder. Apart from this the scapula is rarely affected with tuberculous disease. The acromion process. however, is sometimes the seat of a primary deposit, and, as already stated, this may spread to the clavicle and infect it secondarily.

No special reference to the treatment of these conditions is necessary, as the methods of dealing with caseous deposits elsewhere indicated should be employed here.

Tuberculous Disease of the Shoulder Joint.—Tuberculous disease of the shoulder joint is extremely rare in childhood. This may be illustrated by the fact that in the Hospital for Sick Children, Toronto, where the patients are all under fifteen years of age, not a single instance of this affection of the shoulder was found in the group of three hundred and fifteen cases of tuberculous arthritis admitted to the wards. According to Whitman,* who bases his estimate upon 3,561 cases of tuberculous disease of joints observed at the Hospital for Ruptured and Crippled, New York, the statistics are as follows:

* "Treatise on Orthopedic Surgery," Lea Bros. & Co., Philadelphia.

Vertebræ	1,432 cases	(40.2 per cent)	Elbow joint	62 cases	(1.8 per cent)
Hip joint	1,123 "	(31.5 ")	Shoulder joint	42 "	(1.12 ")
Knee joint	699 "	(19.6 ")	Wrist joint	7 "	(0.2 ")
Ankle joint	196 "	(5.5 ")		3,561	

Thus, in the 315 cases mentioned, there should have been at least 3 instances of tuberculous disease of the shoulder if the same proportion had been maintained.

In the adult, however, while it is a comparatively infrequent manifestation of tuberculous disease, it occasionally occurs.

Anatomical Considerations.—A portion only of the large hemispherical head of the humerus lies in contact with the shallow glenoid cavity of the scapula at any one time; the articular surface of the head of the bone is much more extensive than that of the glenoid fossa. The latter, it is true, is deepened by the glenoid ligament, but the joint is neither osseously nor ligamentously strong; it is dependent upon the muscles which surround it and act upon it, for its stability.

At birth, the upper extremity of the humerus is wholly cartilaginous (Fig. 247). Toward the end of the first year of life, a centre of ossification occurs in the head, followed later by a similar formation in the great tuberosity, and later still in the lesser tuberosity. These three centres unite at the sixth year to form what is described as the upper epiphysis of the humerus, which is separated from the shaft of the bone by an epiphyseal disc of cartilage until the twentieth year of life. This epiphyseal disc of cartilage is shown in Fig. 251, which is a section through the upper part of the humerus and the shoulder joint in a child aged nine. At puberty an osseous nucleus appears also in the margin of the cartilaginous glenoid cavity, which unites at about twenty-five years of age.

The articular capsule is extensive and lax and is attached above to the margins of the glenoidal lip and below to the anatomical neck of the humerus. It is strengthened by the attachments of the tendons of the various muscles which are in contact with it, and by the coraco-humeral ligament passing from the base of the coracoid process above to the tuberosities below. The tendon of the long head of the biceps muscle, arising from the supraglenoid tubercle, passes through the articular cavity, beneath the coraco-humeral ligament; the synovial membrane of the joint accompanies this tendon for a considerable distance outside the joint cavity.

Certain bursæ bear important relations to the shoulder joint. Thus, the subdeltoid bursa, which, as a rule, does not communicate with the joint, lies between the deltoid muscle and the capsule of the joint. Distention of this bursa may be mistaken for effusion into the joint cavity. The subacromial bursa lies between the upper part of the capsule and the coraco-acromial ligament. A third large bursa is found between the subscapularis muscle and the anterior aspect of the capsule. This usually communicates with the joint cavity.

Movements in all directions are permitted at the shoulder joint. It is the most freely movable articulation in the body.

Pathology.—The manifestations of tuberculous disease in the shoulder joint are similar to those met in other articulations. Here, as elsewhere, the disease may be primarily synovial, or the bone may be the seat of the primary infection. It would appear that the bone is more frequently the seat of the primary trouble than the synovial membrane.

When the disease occurs in the humerus it is located in the cancellous tissue forming what is known as the upper epiphysis of the humerus, as is shown in section in Fig. 251. This is almost entirely within the line of reflection of the synovial membrane, and consequently the disease cannot come to the surface without invading the joint cavity in the manner which has already been described as possible in some other articulations. The disease in the bone may eventually result in extensive atrophy of the head. While the primary disease in bone is usually situated in the humerus, it occasionally, though rarely, occurs in the scapula.

Fig. 251.—Section through the Shoulder Joint of a Child Nine Years of Age, showing the Epiphysis of the Upper Extremity of the Humerus. (Original.)

Michel Gangolphe, in Le Dentu and Delbet's "Traité de Chirurgie Clinique et Opératoire," 1896, refers to tuberculous disease of the shoulder joint in the following terms: "In the interesting account published by Audrey and Mondan the statement is made that they examined thirty-two specimens of tuberculous disease of the shoulder joint belonging to the collection of M. Ollier, all of these specimens having been removed from adults or adolescents. The conclusions which they draw from this examination are therefore scarcely applicable to tuberculous disease as it affects the shoulder in young children. Tuberculosis of the shoulder, according to these authors, ordinarily (29 out of 32 cases) manifests itself first in adjacent bone tissue. In 23 of these instances the lesions noted in the humerus plainly predominated over those seen in the scapula, and it was therefore fair to assume that the disease had originated in this bone. In one case, however, there could be scarcely any doubt that it had originated in the scapula. In 10 instances there was only a single lesion in the humerus; in 19 there were multiple lesions; and in 4 both the humerus and the scapula were coincidently involved As has been noted in other regions of the body the epiphysis was the commonest seat of the disease (22 times); in 5 cases the tuberculous lesions involved both the epiphysis and the diaphysis. It is only in exceptional cases (5 out of 32) that the epiphysis escapes, the disease then being located in the adjacent part of the bone; and still more rarely (2 instances) do we find it restricted to the diaphysis."

Chronic abscesses may form, and these usually make their way to the surface about the insertion of the deltoid, but where they burrow extensively they may come into the axilla or infiltrate the tissues over the chest.

The condition of caries sicca, described on page 579, more commonly occurs in the shoulder than in any other joint. In this manifestation of tuberculous disease there is no swelling, but a progressive atrophy of the structures in and about the joint. Dense fibrous tissue forms, the articular cartilage is destroyed, and firm ankylosis eventually occurs. Abscess rarely forms in this condition.

Symptoms.—The symptoms of disease are not as marked in the shoulder joint as in the joints of the lower extremity, mainly for two reasons. First, the joints of the lower limb are constantly brought into action in weight-bearing, and this aggravates the symptoms there, as is not the case in the arm; secondly, the disability produced by stiffness at the joint is masked by the mobility of the scapula. The onset is insidious and the disease runs a very chronic course, as a rule. Pain, often of a neuralgic character, is complained of, and this is most in evidence at night. Local tenderness on pressure usually exists, particularly over the anterior aspect of the joint.

Limitation of movement will be appreciated if the scapula is first fixed and passive movement then carried out. While a certain amount of movement is possible without pain, yet one finds that extreme movement in any direction is resisted by muscular spasm. The movements of rotation are most appreciably affected, the probable explanation being that the scapula cannot contribute by its mobility to these movements as it can, for example, in abduction and adduction.

In the early stages there may be appreciable swelling about the joint, with obliteration of the normal depressions which exist on the sound side, and effacement of the bony prominences to a greater or less extent. The characteristic feature of muscle atrophy manifests itself here, as elsewhere, and the circumferential measurements are usually diminished. Atrophy of the deltoid produces a flattening of the shoulder and causes the margin of the acromion to become unduly prominent. Muscle atrophy will also be present in the arm and forearm.

Abscess formation is common and may come to the surface in front of or behind the deltoid near its insertion. In advanced disease and where mixed infection has occurred, numerous sinuses may burrow widely in and about the shoulder.

When the disease is present in children, the epiphyseal cartilage is usually destroyed, and as a result the growth of the limb in length is interfered with, and it becomes shorter than its fellow. This shortening may be increased by the progressive destruction of the head of the bone.

Diagnosis.—The diagnosis may present considerable difficulty. The effects

of trauma, which have brought about adhesions and limitation of movement, may produce symptoms suggesting tuberculous trouble. The history of the case and the gradual development of the disability in tuberculosis will assist one to form an opinion. Arthritis deformans in the early stage simulates tuberculous arthritis closely. Here, grating on movement, due to erosion of the cartilages, with comparatively slight pain on passive movement, helps one in many instances to distinguish the condition from tuberculosis. The occurrence of a new growth in the shoulder may, in the early stages of its development, produce symptoms like those caused by the presence of a deposit of tubercle. The course of the disease soon clears up the diagnosis; the tumor enlarges without any implication of the joint cavity, and careful examination may enable one to ascertain the true condition of affairs.

If trouble in the shoulder develops in a tuberculous patient, one is assisted materially in forming an opinion of its true nature, the presumption being in favor of tuberculous disease.

Tuberculous disease of the shoulder usually results in some impairment of function. In cases subjected to the expectant method of treatment, we have, as a rule, some degree of permanent stiffness after the disease is eradicated. It is worthy of note that the disease here is more frequently complicated with pulmonary tuberculosis than is the same disease when it involves one of the other joints, and this fact is utilized as an argument by some authorities for early operation in order to establish speedy convalescence, and thus diminish the chances of the supervention of lung trouble.

The results obtained by excision in the adult are satisfactory; a useful movable joint is secured by such means.

Treatment.—Conservative measures may be adopted in the early stages of the disease, and the general principles for providing fixation and rest which have been advised for other joints should be employed. The limb must be secured in good position, as the possibility of ankylosis occurring must be borne in mind, and the attitude in fixation must be that which will prove most serviceable should the joint become stiff. A plaster-of-Paris spica, like that shown in Fig. 252, may be employed. The limb should be slightly abducted and fixed in a position midway between extreme inward and extreme outward rotation. If the case progresses favorably, the fixation apparatus may be abandoned after three or four months, and the arm carried in a sling for a further period of similar duration.

If, however, the disease is making progress, then there should be no delay in proceeding to operative measures. This, in the adult, should take the form of excision of the head of the bone along with all diseased tissue; while in the child a less formal procedure may suffice, depending upon the extent of the disease, an attempt being made to save the epiphyseal disc of cartilage if the amount of disease present should warrant it.

The best method of exposing the shoulder joint for the purpose of eradicating tuberculous disease, is that by an anterior incision. This begins immediately external to the tip of the coracoid process and passes for four inches downward and outward, parallel to the anterior border of the deltoid muscle. The incision is carried through the skin and fascia, while the arm is slightly abducted and rotated outward. The capsule of the joint is exposed in the upper part of the wound, and the tendon of the biceps is defined below. The tendon is

Fig. 252.—Plaster Spica Applied to the Shoulder in Tuberculous Disease of the Shoulder Joint. (Original.)

freed from the groove in which it lies, and the deltoid is raised from the structures subjacent to that muscle and drawn forcibly outward. The front of the capsule is cleared and cut away with scissors. The arm is now allowed to hang vertically over the side of the operating table and the head of the bone is pushed upward through the opened capsule, the muscles attached to the tuberosities being divided as far as may be necessary to effect our purpose. The head is then sawn through, as much of the tuberosities being left as the extent of the disease will warrant. The cavity of the joint is now carefully inspected and all diseased tissue removed. If the glenoid cavity shows evidence of disease, this must also be removed. The wound is then closed in the usual way

and the limb secured in a plaster spica encircling the chest and passing down the limb to the wrist. Cheyne advises that a pad should be placed in front of the joint to prevent the forward displacement of the upper end of the bone, an event which sometimes occurs. After four or five weeks the plaster is removed and passive movement begun. If only a small portion of the bone has been sacrificed, passive movement may be begun as early as the beginning of the third week.

A similar incision and exposure of the joint may be used for the purpose of removing limited foci of disease in the child.

In cases in which bony ankylosis has occurred, a similar operation may be performed and the bone divided by means of a chisel. The cutting should extend through the humerus at the desired level, and by similar means a separation of the articular portion of the glenoid process of the scapula should be effected.

Chronic abscesses which are apt to occur in connection with tuberculous disease in this part of the body, are treated along the lines advocated for such conditions elsewhere. (*Vide* p. 677.) Should mixed infection occur, then the main object to be had in view is to secure efficient drainage.

Amputation might be called for in advanced and neglected cases where the septic processes have produced extensive destruction of the structures in and about the joint, and where the patient's life is endangered by conditions which cannot be relieved by less drastic measures.

Tuberculous Disease of the Elbow Joint.—Tuberculous disease is more common in the elbow than it is in the shoulder. It is, however, a rare affection in the child. Cheyne's statistics showed that 7.9 per cent of all cases of tuberculous arthritis were affections of this joint, but of these the disease manifested itself mainly in young adults, in most of the cases (66 per cent) the disease beginning between the ages of twelve and twenty. One-third of the cases began before ten years of age. Whitman's statistics of 3,561 cases of tuberculous arthritis in the Hospital for the Ruptured and Crippled, of New York, showed 62 (*i.e.*, 1.8 per cent) of elbow-joint disease. Of 315 cases of tuberculous arthritis admitted to the wards of the Hospital for Sick Children, Toronto (*i.e.*, children under fifteen years of age), not a single case of tuberculosis of the elbow was reported. It would thus appear that statistics vary regarding the occurrence of the disease, but it is obvious that it is comparatively infrequent at any age.

Anatomical Considerations.—This is a typical compound joint,—the trochlea of the humerus articulating with the greater sigmoid fossa of the ulna, the head of the radius articulating with the capitellum of the humerus, while the circumferential articular surface of the radial head articulates with the lesser sigmoid notch.

The capsular ligament is extensive and lax, particularly in front and behind.

Its attachment to the humerus is such that it includes within the capsule the three fossæ—the olecranal, the coronoid, and the radial. Laterally, the capsular ligament is re-enforced by the lateral ligaments. The ulnar attachment of the capsule is to the olecranon just below its tip, also on the margins of the great sigmoid notch, and anteriorly to the tip of the coronoid. The radial attachment is such that the entire head and a portion of the neck of the radius are within the capsule, and the radius is held in contact with the ulna by the strong orbicular ligament which is attached to the margins of the lesser sigmoid notch.

In the child at birth the whole of the portion of the humerus within the capsule is cartilaginous (see Fig. 247), as is also the intra-articular portion of the radius. The upper part of the olecranon process is also still cartilaginous. The lower epiphysis of the humerus is formed by the coalescence of three ossific centres which appear in the following order: The capitellum at the third year, the inner part of the trochlea at the twelfth year, and the external condyle also about the twelfth year. The centre for the internal condyle appears at the fifth year and remains as a separate epiphysis. The lower epiphysis of the humerus unites with the shaft at the seventeenth year, and that for the internal condyle at the nineteenth year. The upper ulnar epiphysis is a centre which appears at the upper part of the olecranon process, the greater part of that process having been ossified from extension from the shaft. This appears at the tenth year and unites at the sixteenth. The head of the radius forms an epiphysis. The centre appears at the sixth year and unites with the shaft at the age of twenty. It thus appears that in dealing with the elbow we have cartilage persisting throughout early childhood to an extensive degree. Where such conditions exist, the joint is not prone to the inroads of tuberculous disease. The existence of these various centres of ossification must be borne in mind while interpreting an *x*-ray picture in children.

The strength of the articulation is due, first, to the security afforded by the orbicular ligament which attaches the radius to the ulna; then to the grip which the ulna has upon the lower end of the humerus, because of the conformation of the bones; and, lastly, to the aid which the strong lateral ligaments afford. These facts should be borne in mind, so that the stability of the joint may be preserved in any conservative operation for the eradication of disease.

Of the bursæ about the joint, the following may be noted: the subcutaneous olecranal bursa, situated between the skin and the olecranon, and the internal and external epicondylar bursæ which exist, one over each condyle; lastly, the bicipito-radial bursa between the tendon of the biceps and the neck of the radius. Affections of any of these bursæ—more particularly the subcutaneous olecranal bursa—might be confused with tuberculous disease in the joint.

The movements at the articulation in the case of the humero-ulnar joint

are those of flexion and extension. Similar movements occur at the humero-radial joint, but here rotation also takes place. The movements of rotation (pronation and supination) are carried out both at the humero-radial and at the radio-ulnar joint.

It must be remembered that the axis of the arm is not in line, under normal conditions, with the axis of the forearm. Thus if an individual stands erect, with the upper extremity held vertically at the side, and the palm of the hand looking forward, the axis of the arm lies vertically, but that of the forearm passes downward and outward, forming the so-called "carrying-angle" with the axis of the arm. This should be preserved in operations on the elbow.

Pathology.—The disease begins more frequently in bone than in synovial membrane. Its most frequent site is the olecranon process of the ulna. Next in order of frequency is the humerus, and here most often it is in the external condyle. Much more rarely the disease has been primary in the head of the radius. The trouble may spread to the synovial membrane and infect it secondarily. In advanced disease the ligaments become involved and possibly the bursæ about the joint also.

Symptomatology.—The disease here, as elsewhere, runs a chronic course. Pain at first is slight, and the progressive development of stiffness is often the first symptom of trouble. When pain does appear, it is, as a rule, localized at the elbow and is increased by sudden movement at the joint. Localized tenderness on pressure should be carefully sought for. The joint is superficial and accessible for such examination, and it is sometimes possible to locate a focus of disease in the olecranon before the joint cavity has been implicated.

Swelling is small in amount at the outset, and, when it does supervene, is first noticed on either side of the olecranon and the tendon of the triceps muscle. Later, when the swelling becomes more general, the joint assumes the characteristic fusiform shape, with obliteration of the normal depressions about the joint and effacement of the bony prominences. When the disease is of long duration the swelling may become very great.

The limitation of movement in the early stage is found at the extremes of the arc of motion. Thus complete flexion or extension is resisted by muscular contraction, as is also the movement of pronation or supination in a similar manner. Eventually the joint is fixed in a position midway between extreme pronation and supination. This represents the characteristic faulty attitude which is assumed in advanced disease.

One may be able to detect a slight increase in heat on the affected side. Atrophy of muscle is developed and will be detected by the measurements of the arm and forearm, as compared with those of the sound side. Abscess formation may occur and most frequently appears on the posterior and outer side of the joint.

The *x*-ray may be of service in establishing a diagnosis. Fig. 253 is an *x*-ray

photograph of the right elbow of a lad thirteen years of age who was suffering from tuberculous disease in that joint. The head of the radius is shown to be destroyed. The patient had had symptoms of trouble for four months. An operation was performed and the head of the radius was found to be tuberculous, while a large periarticular abscess had formed which communicated by a sinus with the seat of disease.

Prognosis.—Unless one succeeds in eradicating the disease at a very early stage, the chances of securing a joint free from some degree of permanent stiffness are not good.

Treatment.—Expectant treatment may be carried out with advantage in many instances. The joint is fixed at a right angle by a plaster-of-Paris splint

Fig. 253.—Skiagraph of Tuberculous Disease of the Right Elbow Joint in a Patient Aged Thirteen Years. The disease had existed for four months. The head of the radius is almost entirely destroyed, while the ulna and humerus are normal. (The x-ray picture was taken by Dr. S. Cummings, of Toronto, from a case that occurred in his practice.)

in a position midway between pronation and supination. The splint should extend from the axillary fold to the wrist. The length of time necessary for the maintenance of fixation must vary in individual cases. In early cases fixation for six months may be sufficient, and subsequently the arm is carried in a sling for some months longer, depending upon the progress of the case. In many instances it is found necessary to retain the fixation apparatus for a year. A certain degree of permanent stiffness results, excepting, perhaps, in some cases of pure synovial disease where the trouble has been arrested by efficient treatment at an early stage. After the retention splint has been removed, passive movement and massage may be carried out with a view of grad-

ually increasing the degree of movement and of restoring the normal function of the joint.

Bier's treatment by passive hyperæmia may prove of service, and is advocated in these cases; for a description of the technique see page 590.

Occasionally the case comes under observation with fixation of the limb in a faulty attitude. This is more frequently that of a joint stiff in the attitude of more or less extension. This may be corrected by gradually bringing the joint into the flexed position by manipulation and the application of a plaster-of-Paris splint. The correction of the faulty attitude may be accomplished after a series of such manipulations, the application of each plaster splint securing the limb in an improved position, until eventually the deformity is corrected. It may be necessary to give an anæsthetic in some cases to correct the faulty position.

Should the disease make progress under expectant treatment, then operative interference is indicated. In fact, in the elbow, operative treatment is indicated earlier perhaps than in any other of the large joints when tuberculous disease is present. This is the case because in the elbow tuberculous disease of a progressive character produces marked disability, even when a favorable course is run after expectant treatment, and operative treatment is eminently successful in securing a good functional result.

In children, the operation of arthrectomy, with removal of the diseased tissues, should be the operation of election; while in the adult, excision is the better operation.

The method of opening the elbow joint for arthrectomy or excision suggested by Kocher, of Berne, is perhaps the most generally serviceable. The description is taken from Stile's translation of Kocher's "Operative Surgery." The elbow is flexed to an angle of about one hundred and fifty degrees. An incision is begun over the external supracondylar ridge, two inches above the line of the joint. This is carried vertically downward to the head of the radius, and from thence inward, along the outer border of the anconeus muscle to the outer border of the ulna, which is reached three inches below the tip of the olecranon; finally, the incision terminates by curving over the inner surface of the ulna. The first part of the incision extends downward to the outer border and the external condyle of the humerus, between the supinator longus and the radial extensors anteriorly, and the edge of the triceps posteriorly; below the external condyle it passes down to the bone between the extensor carpi ulnaris and the outer border of the anconeus, and divides the strong capsule over the head of the radius together with the orbicular ligament at its attachment to the ulna. The lower end of the incision divides the lower fibres of the anconeus transversely at their attachment to the posterior border of the ulna, because the muscle extends for a considerable distance down the forearm. The incision, therefore, falls accurately along the interval between the muscles sup-

plied by the musculo-spiral nerve and those supplied by the posterior interosseous, thus avoiding the possibility of subsequent muscular atrophy. The bone having been exposed and the capsule divided, the outer head of the triceps, together with the periosteum and the upper attachment of the capsule, is detached subperiosteally from the humerus, the anconeus from the posterior surface of the ulna, the insertion of the triceps from the tip of the olecranon, and the triceps-anconeus flap is (the joint being extended) displaced over the olecranon to its inner side. The external lateral ligament, with the attachments of the extensor tendons and the capsule attached to the external condyle, are separated subcortically from below by means of a chisel and drawn

Fig. 254.—Skiagraph showing a Tuberculous Abscess in the Lower End of the Right Radius. The patient was fifteen years of age and had complained of disability in the right wrist for three months. The diagnosis was confirmed at the time of operation. (The x-ray picture was taken by Dr. S. Cummings, of Toronto, from a case that occurred in his practice.)

forward. The joint has now become so movable that the forearm can be completely dislocated inward. The whole extensor apparatus, as regards both muscles and nerves, is preserved in its continuity, and the internal lateral ligament is still intact. If complete resection is to be performed, after the joint has been dislocated as above described, the internal lateral ligament is separated subperiosteally along with the muscles from the inner border of the ulna and the internal condyle of the humerus, and the ends of the bones are removed. In separating the lateral ligaments, it is better to remove a shell of bone along with them, so as to preserve their attachment to the periosteum.

After the completion of such an operation the limb is secured in plaster. If the operation consists in an arthrectomy, such as is occasionally advisable in children, the limb is kept at rest in the plaster for three or four weeks, and

subsequently retained in a sling for two or three weeks longer. Passive movement may be carried out after the plaster is removed, and this is specially to be insisted upon as regards pronation and supination.

After excision, the plaster should be removed at the end of two weeks, and gentle passive motion begun. We desire to get a movable joint, and, after excision, it is quite remarkable to what extent the normal movements may be restored. Fixation apparatus may be abandoned after four weeks, as a rule, and, by degrees, free use of the limb is secured.

Where a large amount of bone has to be sacrificed, there is the danger of a flail-like joint. Under such circumstances it is wise to maintain the fixation apparatus for a considerably longer period.

Abscesses forming in connection with tuberculous disease of the elbow must be treated along lines precisely similar to those recommended in the other joints. (*Vide* p. 677.) Where mixed infection has occurred, free drainage is the important thing to obtain, and efficient measures must be adopted to secure it.

Amputation is justifiable only where extensive and destructive septic processes have made it obvious that it is impossible to save a useful limb, and where the patient's life may be endangered.

Tuberculous Disease of the Wrist Joint.—Tuberculous disease of the wrist joint is a rare affection in children, and is not very often met with at any age. Cheyne's statistics gave disease at the wrist as constituting five per cent of the total cases of tuberculous bone and joint disease. Of 315 cases of tuberculous arthritis admitted to the wards of the Hospital for Sick Children, Toronto, there were 4 (*i.e.*, 1.3 per cent) cases of wrist-joint affection.

Anatomical Considerations.—The radio-carpal joint is formed of the following elements: the inferior articular surface of the radius and the inferior aspect of the triangular fibro-cartilage upon the proximal side of the joint, and the scaphoid, semilunar, and cuneiform bones on the distal side. The continuity of the carpal articular surface is in part maintained by interosseous ligaments which exist along the level of the articular cartilage between the carpal bones concerned. The radio-ulnar joint exists, at the wrist, between the capitellum of the ulna and the sigmoid notch of the lower end of the radius; it also extends between the capitellum of the ulna and the upper surface of the triangular fibro-cartilage. This joint is entirely separate from the radio-carpal joint and is associated in its function with the upper radio-ulnar joint in the movements of pronation and supination. The triangular fibro-cartilage is attached to the ulnar margin of the lower articular surface of the radius and to the styloid process of the ulna.

Between the two rows of carpal bones there exists the intercarpal articulation; this constitutes a somewhat extensive and complicated synovial cavity between the carpal bones, forming among these a common joint cavity with the exception of the joint between the pisiform and the cuneiform, which is separate.

This intercarpal joint may in some cases be still more extensive when, as sometimes occurs, the interosseous ligaments, referred to above, are absent; when this occurs the intercarpal joint communicates with the radio-carpal. In similar fashion the intercarpal joint may communicate with the carpo-metacarpal joint. The latter communication is in fact more common than the former. There is a common cavity between the distal row of carpals and the metacarpals, with the exception of the joint between the trapezium and the metacarpal bone of the thumb, which is separate and distinct.

The carpal bones are held together by a series of palmar, dorsal, and interosseous ligaments.

It must be remembered that the lower end of the ulna is cartilaginous until the sixth year, when the centre of ossification for the epiphysis appears; this unites with the shaft at the twenty-third year. Similarly, the epiphysis for the lower end of the radius appears at the second year, and unites with the shaft at the twenty-fifth year.

The carpus is wholly cartilaginous at birth (see Fig. 247). The first carpal to show an ossific centre is the os magnum, at the end of the first year; shortly after, the unciform centre becomes evident; next come the cuneiform at the third year, and the semilunar and the trapezium about the sixth year; then the scaphoid and trapezoid at the sixth or seventh year, and lastly the pisiform at the twelfth year. These facts should be borne in mind in interpreting *x*-ray pictures of the wrist and carpus in a child. Similarly, the development of the epiphyses of the metacarpals and phalanges should be remembered.

The synovial sheaths of the flexor and extensor tendons not infrequently take part in the tuberculous processes about the wrist, and their intimate relations to the bones in this locality demand attention, particularly when operative treatment is undertaken.

Pathology.—Tuberculous disease at the wrist may occur primarily in bone or in synovial membrane; the latter is in all probability the more common. When it commences in bone, the deposit is generally in the lower end of the radius or at the base of the metacarpal bones, generally the second. (Cheyne). Abscess formation is very common in connection with disease here; and tuberculous disease elsewhere in the body, more particularly pulmonary tuberculosis, is not uncommonly present. A tuberculous teno-synovitis beginning in any of the tendon sheaths is often present; it may, in fact, be a primary condition from which invasion of the joints may occur secondarily.

Symptomatology.—Pain, stiffness, and swelling gradually develop. At the outset the degree of limitation of movement is slight and the pain moderate in amount. As the disease progresses, the swelling increases, so that the bony prominences about the wrist are no longer in evidence and the wrist takes on the characteristic fusiform shape of tuberculous arthritis. The swelling is most marked on the dorsal aspect and about the extensor tendons. There is

marked disability, so that the patient is unable to move the wrist without support.

In the later stages the pain becomes severe, particularly when the cartilages are eroded and the synovial membrane, both of the wrist and of the tendon sheaths, becomes infiltrated. Eventually adhesions form in the tendon sheaths and the joints become immobile, usually in an attitude of slight flexion with a tendency to dislocation forward at the wrist joint. The lateral ligaments are not infrequently infiltrated and softened at a fairly early stage, permitting a slight degree of lateral movement at the wrist. Atrophy of the muscles of the arm and forearm occurs as in tuberculous arthritis elsewhere.

Abscess formation is very common, and the abscess first forms on the dorsum, as a rule. Mixed infection is apt to occur, and the part may become riddled with septic sinuses.

The patient's general health suffers markedly in advanced cases. The pain disturbs his rest at night, and his general nutrition is badly maintained.

Diagnosis.—The diagnosis of disease at the wrist is not difficult. The progressive character of the symptoms described is characteristic. The *x*-ray may be of value in determining the extent of the disease. Plate XXVII, Fig. 1, shows disease in the right wrist in a child two years of age. There had been symptoms in this case for three months, and the *x*-ray shows tuberculous disease of the os magnum and the unciform bones, along with the bases of the second and third metacarpal bones.

Treatment.—Expectant treatment should be carried out here with the greatest care, as operative methods of dealing with the disease do not afford a very good prospect of a satisfactory functional result.

The simplest method of fixing the wrist is in a plaster splint applied from the heads of the metacarpal bones to the elbow. The limb should be placed in the most favorable attitude for ankylosis should fixation of the joints occur. The metacarpus should be dorsi-flexed to a slight degree at the wrist. The thumb should be allowed to drop forward, the ball of the thumb rolled inward toward the palm, and the fingers slightly flexed. The fingers should be moved freely every day. This can be most effectively carried out by the patient, who should produce the motion by bringing the muscles into voluntary action, but his efforts must be supplemented by passive movement.

Should flexion deformity exist it may be overcome by degrees, plaster of Paris being used for fixation, and at each application the position should be gradually improved.

The Bier treatment by passive hyperæmia may be carried out with advantage and should be combined with fixation. The technique of the Bier treatment is described at page 590.

Should the expectant treatment fail to effect satisfactory results, and should the disease continue to progress, some form of operative interference is indicated.

Excision of the wrist may be carried out by the method introduced by Lord Lister through two incisions, one upon the dorsal aspect toward the radial side, and the other on the anterior aspect along the ulnar border of the wrist. The operation of excision recommended by Kocher, of Berne, is, however, perhaps the most satisfactory and is accomplished through a single dorsal incision described as a "dorso-ulnar incision." The incision is three and one-half inches long, begins over the middle of the fifth metacarpal bone, and is continued upward over the middle of the wrist joint, and from thence over the middle of the back of the forearm. After the operation has been completed, the limb is secured upon a suitable splint and fixed in the attitude already described in the section relating to expectant treatment.

Abscesses developing in connection with disease in the wrist must be treated along lines elsewhere advocated for other joints (see page 677). When mixed infection occurs, free drainage must be secured by whatever operative means is necessary for accomplishing that purpose.

Amputation is necessary in certain cases. Where septic processes have brought about extensive destruction of the structures about the wrist, and where there is no longer any possibility of saving a useful wrist and hand, one must of course amputate. In individuals in enfeebled health, with perhaps tuberculous disease elsewhere, if operation becomes necessary, it is best to amputate.

Tuberculous Disease of the Metacarpals and Phalanges.—The metacarpals or the phalanges may be the seat of tuberculous disease. The most common manifestation is that in which the shaft of the bone becomes the seat of a deposit centrally. The osseous tissue is gradually destroyed, and while this is in progress new bone is formed under the periosteum. The bone becomes fusiform in shape and appears as if ballooned out in the centre of the shaft. The term "spina ventosa" has been given to this condition. Several phalanges and metacarpals may be affected in the same hand.

Spina ventosa is common in childhood, and is much more common then than it is in adult life.

The appearance presented in this condition is very characteristic. The shape of the bone and the history of the gradual development of the condition render the diagnosis easy. The only condition with which it might be confused is that of tertiary syphilis; the history of the patient will throw light upon the question in a doubtful case.

Treatment.—Rest by suitable splinting, with perhaps compression by means of adhesive plaster, may effect a cure. These cases will often do well after an operation carried out with the view of removing the focus of disease from the bone. The bone should be opened up and thoroughly curetted with a sharp spoon. The wound may then be closed and the part splinted, or it may be packed with sterile gauze and allowed to granulate. Where one cannot save a useful finger it is best to amputate the digit.

Tuberculosis of the Metacarpo-Phalangeal and of the Interphalangeal Joints.—Tuberculous disease in these small joints occurs occasionally. The local manifestations here are similar to those in the larger articulations, viz., a slow chronic enlargement of the joint with a slight amount of pain and stiffness. A joint is sometimes invaded from a bone which is the seat of a spina ventosa, but occasionally the disease is primary in the joint.

Treatment by rest and splinting may be effectively carried out, but operation is usually necessary. In the interphalangeal joint affections, amputation is necessary, as a rule, but, when the metacarpo-phalangeal articulations are involved, excision should be done where there is a good prospect of eradicating the disease by such a method. It is especially desirable to choose excision rather than amputation in the treatment of the metacarpo-phalangeal joint of the thumb.

Tuberculous Disease of the Sternum and Ribs.—The disease here may be superficial, developing as a periostitis and resulting in a superficial caries, or it may begin centrally as an osteomyelitis.

In the case of the sternum, when the surface of the bone is affected on its posterior aspect the disease may spread extensively and its nature may not be determined until an abscess has formed and has made its appearance between the ribs. Such an abscess may be mistaken for a localized empyema.

In the interior of the bone caries may give rise to cavities containing soft necrotic material, or necrosis of bone may lead to the separation of small sequestra.

Abscess very commonly develops, and this makes its way to the surface. If it is not properly cared for, infection by pyogenic organisms is apt to occur, and the septic processes induced result in further destruction of tissue and the persistence of discharging septic sinuses.

The ribs are not infrequently the seat of a tuberculous process, the occurrence of the disease in this locality being practically confined to adults. It may develop as a secondary process in individuals suffering from tuberculous pleurisy, or by extension of the disease from the spine. The middle series of ribs (from the fourth to the eighth) are most frequently affected. The most common manifestation is, in all probability, originally a periostitis leading to superficial caries, but not infrequently the trouble begins as a central lesion producing a chronic form of osteomyelitis.

The rib may be so softened by caries that fracture may occur, or portions of bone may be separated as sequestra. The disease not infrequently presents itself in numerous foci in the same rib, or a series of ribs may become affected. Thus the author had recently under his care a patient in whom five ribs and the sternum were the seat of separate foci of disease.

The symptoms are indefinite at the beginning; a chronic localized swelling, with some tenderness on pressure, is usually the first symptom to attract the

attention of the patient. In the case of the ribs, there may be pain on coughing or on drawing a deep breath. The swelling, which at first is firm and elastic, may subsequently soften and fluctuate as abscess formation occurs. Such an abscess may open into the pleural cavity or upon the skin surface. Occasionally it burrows among the muscles and comes to the surface at some distance from the seat of the osseous disease. An abscess pointing in the loin may develop from disease at the posterior end of the rib, or the abscess may spread into the sheath of the psoas and form a typical psoas abscess. (Cheyne.)

Treatment.—Caseous foci must be opened and curetted; diseased portions of the sternum may be removed. In the case of the rib, where it is possible to diagnose a localized focus of disease, a portion of the bone should be removed, all tuberculous tissue dissected out, and thus the disease may be eradicated and a speedy cure effected. This may be done successfully even where abscess is present; the wound is then closed without drainage, and primary union may be expected.

Should mixed infection occur, then it is necessary to curette thoroughly and establish efficient drainage, the wound being allowed to granulate slowly.

The case frequently runs a chronic course, particularly where there are multiple foci of disease, but there is very little tendency to the development of general tuberculosis, as a rule, and good results may finally be obtained even where extensive disease has existed.

Tuberculous Disease of the Hip Bone, Apart from the Joints.—It must be remembered that a tuberculous deposit may occur in the hip bone quite apart from the articulations which it forms. Here again the region of the epiphysis is apparently more prone to develop the disease than is any other part of the bone. The crest of the ilium, for example, is an epiphysis which appears at puberty and unites at twenty-five years of age. Here tuberculous disease sometimes occurs and may result in an extensive involvement of the crest.

These isolated deposits of tubercle are rendered evident at an early age of their development by persistent tenderness on pressure and some disability while the patient is moving about, pain being produced when the muscles attached to the affected portion of the pelvis are brought into action. The x-ray has been found useful in demonstrating the existence of such tuberculous deposits. The development of an abscess is often the first indication of the true nature of the trouble. This must be treated in the manner elsewhere fully described (p. 677), and portions of the diseased bone which may be laid bare when the abscess is opened should be removed.

Tuberculous Disease of the Sacro-iliac Joint.—Tuberculous involvement of this joint is by no means as common as is similar disease in the hip or knee, but it occasionally occurs and is always to be looked upon as a serious

condition. The disease may begin in either the sacrum or the ilium, and involve the articulation secondarily.

The weight of the trunk is transmitted from the spine to the pelvis through the sacro-iliac joints. The articular surfaces of each of the bones entering into the joint are covered by hyaline cartilage, that on the sacrum being the thicker, but these surfaces are uneven and are not adapted for free movement upon one another. As a fact very little movement is possible at the sacro-iliac joint under normal conditions; Goldthwait and Osgood have demonstrated, however, that a limited amount of mobility is possible; the stability of the joint is secured both by the irregularity of the articular surfaces just referred to and by the strong ligaments which bind the two bones firmly together. The synovial cavity of the joint is very imperfect and rudimentary; in some cases the two surfaces are connected together throughout a part of their extent by fine transverse fibres. Fig. 247 shows a section through the joint in a child one year of age. It will be observed that a layer of cartilage of considerable thickness covers the sacral portion of the joint surface. In this cartilage at the time of puberty an epiphysis appears, and an irregular plate of bone here develops which unites with the lateral mass of the sacrum about the twenty-fifth year. The bones are held together by anterior and posterior sacro-iliac ligaments, and the articulation receives additional support from the great and small sacro-sciatic ligaments. The posterior ligament is very strong and in fact contributes the main ligamentous strength of the joint; it consists of a large number of strong irregular bundles which extend from the rough area above the auricular surface of the ilium to the depressions on the back of the lateral mass of the sacrum. The anterior sacro-iliac ligament consists of thin fibres passing irregularly from the ilium to the sacrum on the anterior aspect of the joint.

The etiological factors at work here are similar to those in the case of disease in other joints (*vide* page 564). It is characteristically a disease of early adult life; it is rare in childhood and in old age, and is most common between the ages of twenty and thirty-five years. If we inquire into the cause of the comparatively late appearance of tuberculous disease of this joint, we may observe that the sacral epiphysis, already referred to, appears late, namely, at the time of puberty, and unites with the bone at twenty-five. It may be that the late appearance of this epiphysis has something to do with the tendency for late manifestation of the disease, as tuberculous affections obviously bear some definite relationship to the developing epiphyses in the neighborhood of which the disease much more frequently occurs than in other portions of the skeleton. In this connection, too, it is significant that the manner in which the disease most commonly starts is in a deposit in the sacrum. Injury is doubtless a common etiological factor.

The joint may be involved primarily or it may be affected secondarily to disease of the lower lumbar vertebræ. When the affection develops secondarily to lumbar disease it most commonly commences as a periostitis. (Cheyne.)

The sacrum or the ilium may be the seat of the primary disease, the deposit occurring in the cancellous tissue of either bone, but the sacrum is more commonly the starting-point. The ligaments may subsequently become involved, and abscess development is not uncommon. When abscess forms, it more commonly spreads downward into the pelvis, as might be anticipated, because the weaker ligament is situated anteriorly.

Symptoms.—The disease is often very insidious in the early stages. A sense of fatigue and weakness in the lower part of the back and in the neighborhood of the joint, with a feeling of insecurity, is complained of. The pain frequently radiates over the buttock and along the course of the sciatic nerve, possibly as far as the knee joint. It is increased by exertion and is most noticeable after walking about during the day, while in the morning some degree of stiffness is present. The pain is increased by sudden exertion, especially on turning the body, or on suddenly rising from the sitting posture. Pain may be elicited, while the patient is being examined in the recumbent posture, by grasping the iliac bones on either side and rocking the pelvis from side to side. If he lies upon the back, and if the foot of the affected side be elevated with the knee extended, the range of motion will be found to be markedly limited and the procedure will often produce pain in the region of the sacro-iliac joint. The explanation is found in the fact that the traction on the hamstrings produces motion at the sacro-iliac joint and consequently pain. There may be tenderness too on direct manipulation over the joint, or by compressing the joint laterally while grasping the two iliac crests. The anterior aspect of the joint in its lower part may be reached by rectal examination, or by way of the vagina, and pain may be elicited by palpation in this region. The existence of a limp while walking is another symptom which is combined with faulty attitude. The patient tends to throw the weight of the body on the sound limb, with the result that the pelvis is lowered and rotated forward on the affected side, and the limb on that side seems elongated; this in turn induces a certain degree of lateral curvature of the spine. Muscular atrophy is present here as in other cases of tuberculous arthritis, and may be noticeable in the buttock, in the thigh, and in the leg. Abscess is a common complication, and in fact the disease may in some instances progress to the formation of an abscess without having previously caused much pain or discomfort; and so the existence of a fluctuating tumor may be one of the first symptoms to indicate the gravity of the condition present. The abscess may appear posteriorly and from the outset exist as an extrapelvic formation of pus, but more commonly it develops anteriorly and is intrapelvic. The pus may pass into the iliac fossa and invade the psoas fascia and eventually find its way into the thigh, or it may work its way through the sciatic or obturator foramen, occasionally passing into the perineum. Sometimes it has ruptured into the rectum. Intrapelvic abscesses may be detected by rectal or vaginal examination. If the abscess ruptures spontaneously,

mixed infection is sure to occur, and then a most serious condition is at once instituted. Persistent sinuses develop, and the patient suffers the usual sequence of events attendant upon long-continued suppuration and discharge, resulting eventually in most instances in a fatal issue.

Diagnosis.—The diagnosis of sacro-iliac disease is occasionally difficult. The condition may be confounded with sciatica, which, however, is more likely to occur later in life than sacro-iliac disease. The recumbent posture will afford relief where the joint is involved, and is not likely to do so in sciatica; then, too, pain produced by rotation of the pelvis is not pronounced in sciatica. Disease of the hip joint may be excluded by careful examination of that articulation, when it will be found that there is no limitation of movement at the hip such as is characteristic of disease there. The existence of sacro-iliac disease having been established it is then necessary to determine whether or not it is tuberculous, and in that regard it must be remembered that arthritis deformans may affect this joint, or again it may be the seat of gonorrhœal arthritis. The history of the case will suggest the diagnosis in these cases.

The *x*-ray as an aid to diagnosis must not be overlooked; positive information may be obtained when disease is present. This consists mainly of the following: the definition of the cancellous bone is not clearly reproduced, the detail of the normal structure is lost, and there is a diffuseness in the picture of the osseous tissue which is in marked contrast to the clear reproduction of the architectural peculiarities of the bone which exist on the normal side.

Prognosis.—The prognosis in sacro-iliac disease is always grave, but the results of treatment in suppurative cases, which formerly were so unsatisfactory, are much better when these abscesses are treated in such a manner as to prevent mixed infection (*vide* page 677). It is not unusual to find that pulmonary tuberculosis is present, and under such circumstances the prognosis is extremely unfavorable because of the failure of general nutrition. The disease usually runs a chronic course, extending over some years, and the outlook must always be serious.

Treatment.—The principles of treatment laid down for tuberculous joints in general (page 586) must be employed here. It is difficult, however, properly to splint the joint. Rest in the recumbent position is necessary in the acute stage, and extension may be applied to the limb of the diseased side in order to steady it and, in turn, the affected joint. A double plaster spica extending from the middle of the calf of the leg up to the mammary line may be applied with advantage where the symptoms are very acute. Woven elastic trunks fitted about each thigh, and then about the buttocks and abdomen, have been suggested by Goldthwait and Osgood. This may be found particularly useful when the patient is able to move about. The same writers have recommended a sacral brace which is useful for conditions of abnormal mobility at the sacro-iliac joint, and which may be employed with advantage

in tuberculous disease. This brace is thus described: "It consists of a sacral pad to which a spring-steel crib is attached. The ends of the crib curve backward, and to these wide webbing belts are attached, which, when fastened in front, because of the curve in the crib part of the brace, crowd the sacral pad firmly against the upper half of the sacrum. The brace is kept in place by attaching it to the corsets by means of steels, and these not only hold the brace down, but, by steadying the lumbar spine, at the same time lessen the tendency to strain the sacro-iliac joints. In order to keep the apparatus in position when the patient is sitting, a narrow strap is attached at the base of the crib, which is tightened when the thighs are flexed and prevents the brace from springing away from the body. This brace, in connection with the elastic trunks in severe cases, has given relief when either alone was not satisfactory."

The joint may be fixed by other means, such as by the application of strips of adhesive plaster encircling the posterior and lateral portions of the pelvis and the lumbar spine, or a strong wide pelvic girdle may prove equally efficient.

When an abscess forms it must receive appropriate treatment, and should it increase in size it should be carefully opened and emptied of its contents; the walls of the abscess should be thoroughly curetted, and then the opening should be closed by sutures without drainage, so as to obtain healing by first intention. The method has elsewhere been described in detail (page 677). Every effort must be made to prevent mixed infection.

Where mixed infection has occurred and sinuses are discharging, then a free opening must be made to secure efficient drainage. Necrotic and carious bone must be removed. In some instances it may be necessary to remove large portions of diseased bone about this articulation. For this purpose Cheyne advises a "long curved incision with the convexity running along the middle of the sacrum and going well above the bones and over the sacro-sciatic notch. The flap is thrown outward and the glutei detached from the bone and also turned outward. The chisel is then applied to the ilium and the sacrum, and the bones chiselled away until the whole joint is excised, or till the bone deposit is found and removed." An operation of this magnitude is necessarily a very serious undertaking, as a patient requiring such measures, because of extensive and destructive disease in the joint, must already be much weakened by continued suppuration.

Tuberculous Disease of the Symphysis Pubis.—This joint is rarely the seat of tuberculous disease. It is not as important functionally as the sacro-iliac joint, as indicated by the fact that a sufficient degree of pelvic stability is preserved when the joint is deficient. Thus, in ectopia vesicæ the pubic symphysis is not present, and yet the individual is able to stand and walk in a normal fashion; so, too, congenital absence of the pubic bones, without interference with locomotion, has been recorded. The surfaces of the bones at the symphysis are covered with a layer of cartilage. Between these two surfaces

there is interposed a mass of dense connective tissue, partly fibro-cartilage, in the midst of which is a slit-like space running vertically and lying nearer the posterior than the anterior part of this so-called interpubic fibro-cartilage. An epiphysis is developed in connection with the cartilage over the pubis; this appears at puberty and unites at the age of twenty-five. The symphysis is surrounded by fibres which are attached to the bone and constitute the pubic ligaments which are situated on the various aspects of the joint. Of these the anterior is the strongest; the inferior ligament is also well developed, but the superior and the posterior are both weak.

Tuberculous disease in this locality does not, as a rule, present any peculiar feature. In one case, however, which was admitted to the Hospital for Sick Children, Toronto, the patient, a lad of seven years, was affected with tuberculous disease of this articulation; and, in connection with the disease, an abscess had formed, and a small sequestrum had ulcerated into the urethra and produced a urinary fistula.

The treatment of tuberculous disease of the symphysis pubis consists of rest in the recumbent posture when there is evidence of acute disease. Abscesses must be treated in the manner elsewhere described (page 677); and, should sinuses exist, free drainage must be provided after such operative measures have been adopted as may be necessary to remove diseased structures in and about the joint.

Tuberculous Disease of the Hip Joint.—This is by far the most common affection of the hip joint. In the Hospital for Sick Children, Toronto, of 249 cases admitted for surgical treatment of the hip joint, 225 (or 90 per cent) were for tuberculous disease. In the same institution tuberculous disease of the hip constituted a very large proportion of all joint affections (including the spine); thus, of 608 cases of surgical affection of the joints, 225 (or 37 per cent) were cases of tuberculous hip disease. These figures refer, of course, to children, and, in the hospital mentioned, the age limit for admittance is fourteen years. While morbus coxæ is undoubtedly more common in early life, and certain of the other affections of the hip are more frequently met with in the adult, still, when we include diseases of the adult in our statistical table, we find the proportion of tuberculous cases very high. Thus Koenig classifies 757 surgical affections of the hip as follows:

1. Tuberculosis	568
2. Acute arthritis (after typhoid, scarlet fever, etc.)	110
Coxa vara	5
Tumor	2
3. Gonorrhœa	30
4. Arthritis deformans	22
5. Contracture and ankylosis from unknown cause	6
6. Pyæmic affections	3
7. Wounds (in dislocations and fractures)	11
	757

Koenig therefore found that 75 per cent of all surgical affections of the hip were tuberculous in character.

From the investigations of Whitman one is forced to conclude that coxa vara is much more common than these statistics of Koenig would lead us to believe.

Then, again, the cases of tuberculous arthritis admitted to the Children's Hospital, Toronto, being taken by themselves, it was found that hip-joint disease was the most common among these. The comparatively small record of 315 cases was as follows:

Hip-joint disease	179
Spinal disease	70
Knee-joint disease	52
Ankle-joint disease	9
Wrist-joint disease	4
Metacarpal disease	1

showing that, in all cases of tuberculous arthritis admitted, 53.6 per cent were affections of the hip joint. These statistics are somewhat at variance with those of Cheyne and others, who found that in children tuberculosis of the spinal column was the most common tuberculous bone affection. Cheyne found that from 40 to 46 per cent of all cases of tuberculous bone affection in children were located in the spine, while in my statistics only 22 per cent were spinal cases, and by far the largest proportion of cases were of disease of the hip joint. (See also the statistics given by Whitman, on page 602.)

The marked tendency for the disease to be restricted to the early years of life is shown by Koenig's statistics, as follows:

1– 5 years	152
6–10 "	149
11–15 "	102
16–20 "	60
21–25 "	18
26–30 "	10
31–40 "	15
41–50 "	4
51–60 "	3
Not recorded	55

The immunity of older people from tuberculous disease of the joints may, however, be overestimated because of the fact that fewer people are alive at fifty than at ten years of age. Reference has been made to this fallacy at page 567. Certain authors have in fact held that the two extremes of life present the greatest liability to the disease, and experience would seem to show that this view is correct.

Anatomical Considerations.—The upper extremity of the femur at the time of birth is wholly cartilaginous; the trochanter major, the neck, and the head

form a continuous piece of cartilage which caps the osseous extremity of the shaft. The head lies in the acetabular fossa, and the acetabulum at this period of development is also cartilaginous to a very large extent. In Fig. 247 we have a frozen section through the hip joint of a child one year old; a centre of ossification has appeared in that part of the cartilage which is to form the head. The entire thickness of the floor of the acetabulum at its centre is seen to be cartilaginous; this constitutes the "Y cartilage," which persists between the individual elements of the hip bone which meet in the acetabular fossa. Osseous union of the three elements of the hip bone is not completed until the time of puberty. It is not until the sixth year that the extension from the shaft of the bone which forms the neck develops sufficiently to cut off the cartilage

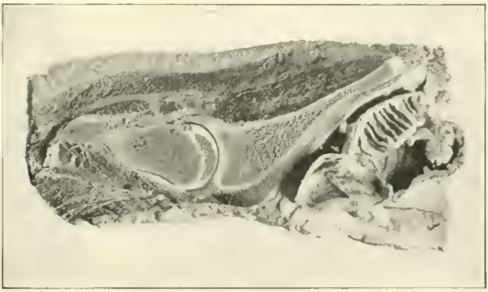

Fig. 255.—Section through the Hip Joint of a Child Nine Years of Age, showing the Epiphysis of the Head of the Femur separated from the Neck by Cartilage. (Original.)

forming the great trochanter from that of the head; it is during the fourth year that an ossific centre for the trochanter appears. Fig. 255 is a photograph from a frozen section of the hip joint of a child nine years of age; it will be seen that the head is separated from the shaft by an epiphyseal line of cartilage. The layer of cartilage separating the head from the neck presents a curved outline in the section, the reason being that the layer of cartilage in question, with the adjacent portion of the osseous head, is concave toward the neck of the bone; this prevents separation of the epiphysis by traumatism, although separation along this line by tuberculous disease is not uncommon. The epiphyseal cartilage separating the head disappears at eighteen or twenty years of age; the cartilage separating the trochanter, at eighteen years of age.

The insertion of the capsule into the femoral neck and its relations to the neck and head are such that they must be studied and reckoned with in connection with articular disease. In the first place, it must be remembered that the acetabular cavity is considerably deepened by a strong circular fibro-cartilaginous ligament (the cotyloid ligament) forming the so-called glenoidal lip. The portion of the glenoidal lip which bridges over the cotyloid notch consti-

tutes the so-called transverse ligament. The articular capsule of the hip joint arises from the outer surface of the glenoid lip and surrounds not only the head of the femur, but the greater part of the neck. Anteriorly the capsule extends to the anterior intertrochanteric line and is attached there; posteriorly it does not extend quite so far. The result is that the whole of the femoral neck

Fig. 256.—Section through the Hip Joint of an Adult, showing the Acetabular Fossa and the Ligamentum Teres. (Original.)

is embraced in the capsule anteriorly and somewhat more than half of it posteriorly. The articular capsule is strongly developed and it is markedly reinforced by accessory ligaments. These accessory ligaments are composed of longitudinal and circular fibres and are firmly adherent to the capsule. The orbicular ligament (the zona orbicularis of Henle) surrounds the narrowest portion of the femoral neck, constituting a very definite and important band of circularly disposed fibres. It is completely covered by the other ligaments

and surrounds the neck of the femur like a ring, being, however, most strongly developed above, behind, and below; it is attached to the bone below the anterior inferior iliac spine.

The longitudinal fibres constitute the ilio-femoral, pubo-capsular, and ischio-capsular ligaments. Of these the ilio-femoral is the most important; it passes from the anterior inferior iliac spine to the anterior intertrochanteric line, and in cases of effusion into the hip joint the tension upon this ligament has the effect of pressing the head of the femur into the acetabulum; the position of flexion at the joint is assumed in order that this ligament may be relaxed and the pain relieved. In three different localities the capsule of the hip joint is thin. On the posterior aspect a thin part exists above the zona orbicularis, between the ilio-femoral and the ischio-capsular ligaments. A second thin part exists in the lower part of the capsule below the zona orbicularis, between the pubo-capsular and the ischio-capsular ligaments. A third weak part exists on the antero-internal part of the capsule immediately internal to the ilio-femoral ligament, between this and the pubo-capsular ligament. This last weak spot on the anterior aspect deserves further notice because at this point the ilio-pectineal bursa, which lies between the ilio-femoral ligament and the ilio-psoas muscle, occasionally communicates with the joint cavity; according to Heinecke, the communication occurs in one in thirteen cases. Even where there is not an actual communication, the wall of the bursa on its deep surface is always thin, and it is not unusual for effusion of pus to make its way through to the bursa from the joint, or tuberculous invasion of the synovial membrane of the joint may here burst through and infect the lining of the bursa. It is said also that a psoas or iliac abscess may pass beneath Poupart's ligament and invade the hip joint by way of the ilio-pectineal bursa. Similarly, tuberculous disease may pass beyond the joint cavity at the other two weak points in the capsule, *i.e.*, at the thin part of the capsule on its posterior aspect, or at that already spoken of as being on its lower part.

The floor of the acetabulum is made up of two portions—a semilunar part, forming the upper and lateral portions, and, below it, a quadrilateral portion embraced in the concavity of the semilunar part. The lower extremities of the semilunar portion form the margins of the cotyloid notch. The quadrilateral surface referred to above differs from the semilunar portion in that it is not covered by cartilage, but has a rough and uneven surface; it is described as the *acetabular fossa*, and does not come in contact with the head of the femur, but is separated from the head by a cushion of fat covered by synovial villi. From this pad of fat and from the cotyloid notch arises the ligamentum teres, which in reality is a flat band, and not round. This ligament is inserted into a depression on the head of the femur (see Fig. 256) and further separates the head from the acetabular fossa. Nutrient vessels pass to the head of the femur in the round ligament. This seems to be the main function of this ligament, as

it serves no mechanical purpose in the hip joint, being too long and soft to take any part in checking joint movements. When tuberculous disease progresses to any marked extent in the hip joint, the ligamentum teres is soon destroyed, and in cases which come to operation it is seldom distinguishable. Its early destruction in hip disease may be a factor in bringing about necrosis of the head in tuberculous disease because of the interference with the blood supply which must result. It is important to observe in this connection that this ligament is not always present in health, and, also, that its vascularity is lessened by, and may disappear with, advancing age. Tuberculous disease, however, invades the pad of fat and the synovial tufts connected with it. When these structures in the acetabular fossa are destroyed, the more likely is luxation of the joint to take place as the result of disease.

A bursa exists between the gluteus maximus and the posterior and outer part of the trochanter major. This is known as the *trochanteric bursa*. This bursa may be the seat of a cold abscess, and a fluctuating intumescence on the posterior part of the limb in this locality would suggest the probability of a tuberculous lesion in the trochanter, which lesion has invaded the bursa and has resulted in abscess formation. The bursa may similarly be invaded from a tuberculous lesion in the upper part of the femoral shaft, but it is not likely to be involved in disease confined to the joint cavity.

Etiology.—The factors which produce tuberculous disease in the joints have already been fully considered (*vide* page 564). Traumatic causes are those which receive most consideration as predisposing to the production of disease in the hip. Koenig's statistics would suggest that injuries are not so frequently the starting-point of this disease as is generally believed. He found a history of injury in only 15.1 per cent of his cases of hip disease. This percentage is, in our opinion, much too low; we agree with those who look upon trauma as a starting-point in the disease in a very large proportion of cases. We have discussed the relationship of trauma to tuberculous arthritis fully at page 565. Heredity played a part in the history of Koenig's cases in 35.4 per cent. Tuberculous hip disease has been known to follow scarlet fever, measles, whooping cough, diphtheria, chicken-pox, and typhoid fever. In a large proportion of the cases which come under observation, however, we are unable to obtain a history of any predisposing cause.

Pathology.—The tuberculous invasion of osseous tissue and of synovial membrane has been already described (page 573). In the hip joint the starting-point may be in the synovial membrane or in the bone. The origin is probably more frequently in the bone than in the synovial membrane. It would appear that the cartilage is never primarily affected. When the disease begins in the synovial membrane, it seems commonly to take its start from the synovial tufts which surround the ligamentum teres and from the pad of fat in the acetabular fossa. From these points the disease may rapidly

spread over the entire synovial membrane of the joint, but, because of the anatomical relations of the acetabular fossa and its contents (see page 627, also Fig. 256), we find that occasionally the disease spreads to the extra-articular tissues without invading the joint cavity, so that there may even develop an abscess which had its starting-point in the acetabular fossa and which may eventually come to the surface without any serious involvement of the hip joint in the disease. This possibility must be borne in mind in the operative treatment of cold abscesses. As already stated, the ligamentum teres disappears early in tuberculous invasion of the joint, and in cases which come to operation it is very rarely recognizable.

The disease as manifested in the bone may be solely in the form of caries, but the formation of a sequestrum is very common. The invasion may be primarily in bone; and, when that is the case, the deposit may be found in various localities. Thus, the disease may be located in the acetabulum or in the femur. When it is located in the femur we find that the head of the bone is the most frequent site. Caries may occur in the head and leave for a time the cartilage covering it intact; it is not uncommon to find comparatively normal cartilage completely separated from the diseased bone beneath. Eventually, however, the cartilage is involved secondarily, it becomes perforated in places, and is at last wholly destroyed. The primary focus in the bone may be in the neck, below the epiphyseal cartilage, or it may be removed a considerable distance from that cartilage and exist in the outer part of the femoral neck, or in the trochanter, or in the upper portion of the femoral shaft. On the acetabular side the deposit is frequently in the iliac portion of the bone. Sometimes, and the fact should be carefully noted, a tuberculous deposit may exist in the ilium quite above the acetabulum. The relative frequency of occurrence in these different localities may be judged from Koenig's statistics of his findings in 381 cases of excision of the hip joint. These are as follows:

Head of the femur	146
The acetabulum	187
The femoral neck	28
The trochanter	5
The femoral shaft	5
The pelvis above the joint	10
	381

Of the 146 cases in the femoral head it was found that—

The disease was primary in the head in	44 cases
The disease was secondary in the head in	48 "
The question was undetermined in	54 "

Of the 187 cases in the acetabulum—

The disease was primary in	98 cases
The disease was secondary in	49 "
The question was undetermined in	40 "

One would conclude from these results that primary disease in the acetabulum is more common than primary disease in the femoral head. This is quite contrary to the generally accepted belief that primary disease is more common in in the head than in the acetabulum.

Definite statistics are not available to show the comparative frequency of primary disease in the bone and in the synovial membrane, respectively. Clinical observation made with a view to determine this point is not easily carried out in the hip, but the view generally held, and in which we concur, is that the bone is more commonly the seat of the primary deposit.

The disease in the joint may progress until more or less complete disintegration of the joint structures occurs. Destruction of the articular cartilage takes place with absorption of the osseous elements entering into the joint structure. By reference to Figs. 247, 255, and 256 it will be seen that the head of the femur presses upon the upper part of the acetabulum, and the overlying thickened iliac portion is the part which receives the pressure of the head. So it is we find that the tonic contraction of the muscles in hip disease produces its effect by pressure in the direction indicated, and there occurs an absorption of the upper and back part of the acetabulum with a travelling of the head of the femur upward and backward upon the dorsum ilii; a growth of new bone may make an osseous ridge against which the dislocated head impinges at a higher level. This has been described as enlargement or "wandering of the acetabulum." Occasionally something approaching the conditions found in true dislocation obtains, so that the head is dislocated out of a comparatively normal acetabular fossa. This occurs as the result of the growth, in the joint cavity, of tuberculous tissue which fills up the acetabulum and thus dislodges the head of the bone, the diseased and softened ligaments permitting the head to pass upward over the upper rim of the acetabulum on to the dorsum ilii. This may the more readily occur when there is partial or complete disappearance of the head as the result of disease; under such circumstances the upper portion of the neck may ride on the dorsum of the ilium. Occasionally the head is detained against the acetabular margin, which becomes grooved at the point of pressure. Rare instances are on record where the head of the bone has been dislocated in other directions; thus Cheyne observed two cases where it had passed forward on to the pubis.

Chronic abscesses are very common in hip-joint disease. When these originate within the joint cavity they are likely to rupture through the capsule at its weak points (page 627) and appear on the antero-internal aspect or posteriorly. The abscesses spread in the direction of least resistance; thus, when appearing anteriorly, they often pass between the gluteus minimus and the rectus tendon and then between the tensor fasciæ femoris and the sartorius, and thus reach the fascia lata and the surface; on the inner aspect an abscess may pass down among the adductor muscles toward the knee. Posteriorly the

abscess may burrow among the glutei muscles. The pus may invade the iliopectineal bursa and spread upward under Poupart's ligament, there forming an iliac abscess. Then, again, perforation of the floor of the acetabulum, or acetabular disease short of perforation, may give rise to a pelvic abscess which proceeds to occupy the iliac fossa, or may spread downward into the ischiorectal fossa or pass out through the sacro-sciatic foramina to point in the gluteal region. When the disease is in the outer part of the femoral neck or in the trochanter, there may develop, in connection with it, an abscess that has no communication with the joint cavity.

Symptomatology.—The disease is frequently very insidious at the onset. The first symptom of trouble to attract attention is the existence of a limp when the child walks. Pain is occasionally an early manifestation of the disease, but it is frequently so insignificant that no complaint is made and the existence of pain or tenderness is found only on examination; even then one may fail to elicit it. Restriction of the normal movements of the joint exists to a greater or less degree. The limb is caused to assume a characteristic attitude of flexion abduction and rotation outward. Muscular atrophy is found when one compares the measurements of the diseased side with those of the sound side. As the disease progresses, and destructive changes occur in the joint, one finds that the attitude of the limb is altered; it becomes adducted and inverted, flexion still persisting. Pain may be greatly increased or may still be slight in degree. In a great many cases the limb is rotated outward instead of inward in this late deformity; this is apparently the case, at all events, when dislocation on to the dorsum ilii has not yet occurred. Abscesses may form and there may be marked constitutional disturbance. It may be well to discuss these various symptoms individually and to indicate their significance during the various stages in the progress of the disease.

Lameness.—The child limps, and this in many cases is the first noticeable symptom. This limp may be assumed without any conscious knowledge on the part of the child that he is thus in a mechanical fashion protecting the hip joint. When asked why he limps he may be unable to explain. The limping is, as a rule, more marked in the morning, often apparently disappearing during the day; the patient tends to throw his weight upon his toes rather than jar the sensitive hip by coming down upon the heel; he does not fully extend the hip while walking, the knee being slightly flexed, and he maintains his weight for a shorter time on the diseased limb than he does on the sound limb. The lameness may be intermittent in character, and so the mere absence of a limp at the time of an examination should not exclude hip-joint disease from one's diagnosis. At later periods of the disease lameness may be the result of deformity of the limb; thus there may be shortening or dislocation to account for it; in certain cases ankylosis is the cause of the disability.

Pain.—This is a variable manifestation of hip disease. It may be entirely

absent at first, and the disease may make considerable progress without inducing pain. On the other hand, pain may be the first symptom to attract attention, and in acute cases it may be very severe. There are certain characteristic features of the pain in hip disease; of these the one most worthy of note is the reference of pain to the knee rather than to the hip. This has proved so misleading that the knee has frequently been assiduously treated on the false assumption that it was the seat of trouble, when a careful examination would have revealed the fact that hip disease was the cause of the referred pain. The associated nerve supply of the two joints is accountable for the error. Branches from the anterior crural, the obturator, and the sciatic nerves supply the hip

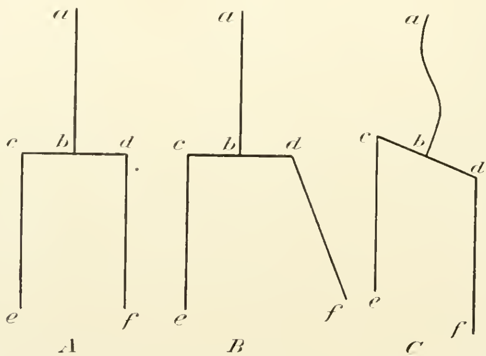

FIG. 257.—Diagram Representing the Attitude of Abduction. The figure is explained in the text.

joint, and these three nerves are again represented in the knee joint. It further has been claimed that the pain induced along the course of any one of these nerves individually may aid us in diagnosing the starting-point of disease in the hip. Thus, the ligamentum teres receives its nerve supply from the obturator, and the geniculate branch of the same nerve passes to the inner side and to the interior of the knee joint; if the ligamentum teres is the part primarily involved at the hip, then, while the disease is restricted to the region of that ligament, pain is complained of at the knee on the inner side of the joint and in the interior thereof. If again the anterior part of the joint is affected, *i.e.*, in the region supplied by the anterior crural, then the referred pain at the knee is experienced on the anterior part of the joint. When the posterior part of the capsule of the hip is affected, then pain may occur at the back of the knee and may even extend to the heel or into the foot. It must not be supposed that pain in the knee is an invariable accompaniment of hip disease, for such is not the case. The pain may be restricted to the hip.

The pain in hip disease is not constant and is often induced by some sudden

movement, or it may occur quite spontaneously without any apparent exciting cause. In children "night cries" constitute a distressing manifestation of pain. The child will suddenly cry out, will waken from sleep, and may often be found holding the thigh in a firm grasp. At other times a sharp cry occurs during sleep which is uninterrupted. It has been claimed that the night cry indicates implication of the articular cartilage in the disease, but there is no

FIG. 258.—Tuberculous Disease of the Hip in a Child aged Six Years. The attitude of abduction and outward rotation is shown by means of tapes placed over the axes of the limbs and between the anterior superior iliac spines. (Original.)

good ground for this assumption. The sudden pain during sleep is due to the contraction of muscles which during the waking hours have been on guard but have become relaxed during sleep, and then, because of some sudden muscular spasm, the articular surfaces of the hypersensitive joint are pressed together and pain is produced. Night cries may be repeated frequently—as many as fifteen or twenty times during the night.

The intensity of the pain varies greatly. In very acute cases it may be severe, so much so that the slightest change in position may cause great suffering. During the manipulation necessary for the examination of the joint, pain may be produced by pressure upon the trochanter, or the whole limb, grasped

at the ankle, may be suddenly jerked upward so as to cause sudden pressure between the joint surfaces. Pressure anteriorly over the joint frequently elicits pain.

The Attitude of the Limb.—In the early stages of hip-joint disease the limb is caused involuntarily to assume a characteristic attitude. Flexion, abduction, and rotation outward are brought about. When the limbs are

Fig. 259.—The Same Patient as Fig. 258. The picture shows that, when the limbs are brought into a position in which they are parallel, the angle of abduction is preserved and apparent lengthening is produced. (Original.)

brought parallel with one another and the angle of abduction is preserved, there must necessarily be, as a result, an apparent lengthening of the affected limb. Reference to Fig. 257 will at once make this clear. In the figure the line *ab* represents the axis of the spine, *cd* the transverse axis of the pelvis, and *ce* and *df* the axes of the lower extremities. In A the normal relations of these axes to one another are represented; in B the relation which obtains in abduction of the left lower limb is shown. In C the limbs are brought into a position in which they are parallel, and as a result, there is apparent lengthening of the abducted limb with tilting of the pelvis, inducing secondary lateral curvature of the spine, while the angle of abduction is maintained.

Thus it will be observed that abduction may be masked by the tilting of the pelvis. The tilting of the pelvis is best estimated by observing the height of the anterior superior spine of the ilium on the abducted side, which will be found at a lower level than on the sound side. Figs. 258 and 259 are photographs of the same patient; in the former the affected limb is abducted from its fellow and the pelvis is straight, while in the latter the limbs are brought together and the angle of abduction is preserved by tilting the pelvis. The amount of apparent lengthening may be estimated by measuring from the umbilicus to the internal malleolus on the affected side and comparing that with a similar measurement on the sound side. The real length of the limbs will be determined by placing the two limbs in the same degree of abduction and the same degree of flexion, and measuring from the anterior superior iliac spine to the

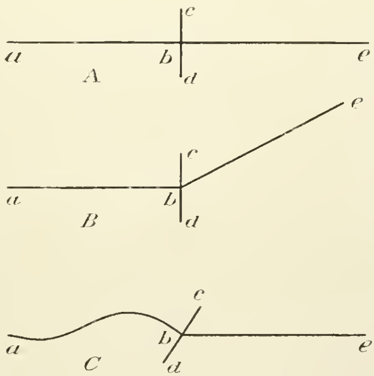

FIG. 260.—Diagram Illustrating the Attitude of Flexion. The figure is fully described in the text.

internal malleolus. In the existence of apparent lengthening there may still be real shortening. Thus Koenig found real shortening in 83 out of 267 cases in which abduction existed, *i.e.*, thirty-one per cent.

Flexion at the hip may similarly be masked by tilting the pelvis on its transverse axis and curving the lumbar spine. Fig. 260 illustrates the method of bringing this about. The line *ab* represents the axis of the spine, which, for the purpose of illustration, may be considered a straight line; *cd* represents the antero-posterior axis of the pelvis, and *be* the axis of the limb. The normal relations of these axes in the supine position is shown in A; while in B the axes are shown in the relations they would bear to one another when the lower limb is flexed. When, however, the limb lies flat upon the table the angle of flexion is preserved by tilting the pelvis, the effect of which must necessarily be to throw the base of the sacrum forward and to produce a lordosis of the lumbar spine. Fig. 261 is a photograph of a patient showing flexion.

The boy is lying flat upon a table, and the lordosis of the lumbar spine is indicated by the tapes attached to his body. If the limb is raised, the angle of flexion is preserved by tilting backward the pelvis on its transverse axis, when the lordosis disappears, the back lying in contact with the surface of the table. This attitude is illustrated in Fig. 262. The angle of flexion may now be calculated by using a goniometer, as shown in the figure. More accurate measurements may be obtained by eliminating the effect of extension of the sound limb, and in Fig. 263 this method of determining the degree of fixed flexion of the hip, as suggested by Whitman, is indicated. The sound limb is flexed acutely so as to hold the lumbar spine in contact with the table, the diseased limb rises up and is maintained in its attitude of fixed flexion, and the angle of flexion of the diseased side is then estimated.

A certain amount of lordosis is normal in the lumbar spine, and, where the

FIG. 261.—The Same Patient as Fig. 262. The illustration shows the lordosis of the lumbar spine when the limb is brought down flat upon the table. (Original.)

buttocks are unusually well developed, a space may exist between the lumbar spine and the table even when the thighs are extended. This fact must be remembered if we wish to prevent error in our conclusions.

This attitude of flexion, abduction, and rotation outward is the natural resting position of the limb. Thus, if one recalls the characteristic attitude of ease assumed by an individual while sitting upon a chair, it is seen that the thighs are abducted from one another, there is a slight rotation outward, and there is flexion at the hip joint. It seems, therefore, natural that in conditions of disease, when nature demands rest, this characteristic attitude should be assumed. The experiments made by Bonnet many years ago throw some light upon the assumption of this attitude in early hip-joint disease. Bonnet injected the healthy hip joint in a cadaver, under pressure, and found that it assumed a position of flexion, abduction, and rotation outward. The experiment is not as conclusive, however, as might appear at first sight, because a very considerable degree of pressure is necessary within the capsule in order to produce the attitude in question in the cadaver. In the presence of effusion into the joint

one would expect this attitude in order to accommodate the joint cavity to the effused material, and this is undoubtedly the case in acute synovitis. In hip-joint disease, while there is seldom, if ever, much effusion, nevertheless the thickening of the synovial membrane, where that exists, or the sensitiveness of the joint structures, may have the same effect. Flexion, rotation outward, and abduction relax the strong ilio-femoral ligament, and this is probably the true explanation of the assumption of the attitude in question; the sensitive structures are protected from pressure, and, while a considerable degree of movement may be carried out painlessly, nevertheless any attempt to produce

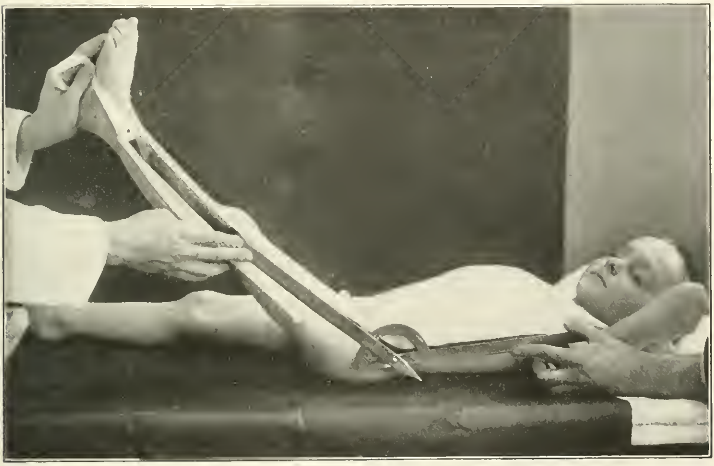

Fig. 262.—Tuberculous Disease of the Hip in a Child Six Years of Age. The amount of flexion is calculated by means of the goniometer. The limb is elevated until the spine lies flat upon the table, when the angle of flexion is estimated. (Original.)

full extension or complete adduction is resisted and produces much pain. It is obvious, also, that with the thigh flexed there is less jar produced in the sensitive joint when the patient moves about.

In some instances, even in the early stages of the disease, the thigh is flexed, rotated outward, and adducted instead of abducted; this may occur when the process is very acute, and we may imagine that in such cases early extensive destruction has been done to the joint tissues, resulting in softening of the ligaments and thus permitting the joint to assume this attitude through muscular spasm without inducing the tension within the joint which demands abduction under other conditions. The attitude of adduction and inward rotation with flexion is, however, a very constant condition in the later stages of the disease when there has been absorption of the head of the bone, or when the

acetabulum is altered in shape, and when dislocation of the femur on to the dorsum of the ilium takes place. This attitude of adduction and flexion is well shown in Fig. 283, which represents a patient in whom the disease had become quiescent. In this case, however, the limb is rotated outward. The assumption of this attitude is purely mechanical in nature, and may be compared to the position of the limb in an ordinary traumatic dislocation on to the dorsum ilii of a healthy joint.

Fig. 264 shows a patient with adduction and inward rotation with tilting upward of the pelvis on the affected side. If in this patient the foot of the adducted limb were carried across the foot of the opposite side, the pelvis

Fig. 263.—The Same Patient as in Fig. 262. The illustration shows Whitman's method of determining the amount of flexion by flexing the other thigh so as to hold the lumbar spine in contact with the table. (Original.)

would be restored to its normal position, and the angle of adduction would be preserved. If the adducted limb were carried away from its fellow, the angle of adduction would still be maintained by tilting the pelvis markedly upward on the affected side. In these cases the effect of adduction with tilting upward of the pelvis on the diseased side is to produce apparent shortening of the affected limb. This may be estimated in the same fashion as that suggested in apparent lengthening. Along with the apparent shortening there may be, and probably is, real shortening because of absorption of the head, of shortening of the neck, or of changes in the acetabulum with dislocation upward and backward. Koenig found that out of 232 cases in which adduction was present there was real shortening in 164, *i.e.*, seventy-one per cent.

While we have thus described the characteristic attitudes assumed in the different stages of hip-joint disease we must record the fact that some departures from the usual conditions are occasionally noted. For example, if the patient is confined to bed or does not walk, as in hip disease in infancy, the attitude of abduction may persist, even when the muscular spasm is intense. Thus it would appear that locomotion has a distinct influence on the character of distortion. (Whitman.) Then, again, while the abducted limb is usually rotated outward and the adducted limb rotated inward, the reverse may be the case. These unusual conditions are probably the result of the special treatment to which the joint has been subjected. It is a question whether or not internal rotation actually exists in the adducted cases. I have observed many instances where the reverse was true, and, curiously enough, most of the patients photographed and published do not show the internal rotation which is ascribed to them. Lastly, it may be noted that Koenig reported three cases in which real lengthening of the affected limb was observed.

Fig. 264.—Tuberculous Disease of the Left Hip in a Child Aged Seven Years. The picture shows adduction with tilting upward of the pelvis on the affected side. (Original.)

When abduction, flexion, and rotation outward exist, the buttock is flatter and broader on the affected side than on the sound side; because of the flexion the gluteo-femoral furrow is shallower, or may become completely obliterated, while the tilting downward of the pelvis causes it to be lower than its fellow of the opposite side. On the other hand, in adduction this furrow is shortened and elevated; on the anterior aspect of the limb the inguino-femoral furrow is deeper and longer in adduction and flexion, while abduction tends to make it less marked. The intergluteal furrow and the genitals point away from the abducted thigh and toward the adducted thigh.

Restriction of Movement.—This is a characteristic phenomenon in all cases of tuberculous arthritis. The characteristic attitudes assumed by the limb at the various stages in the development of the disease have been described.

Thus, in the early stages, when the limb is in a position of abduction, flexion, and rotation outward, limitation of movement is a very characteristic feature of the case. It must be remembered, however, that movement within certain limits may be very free, and the importance of this observation cannot be too strongly urged, as an error in diagnosis may be made, because it might be assumed that disease could not exist where such free movement is possible.

FIG. 265.—Ankylosis with Flexion Deformity in Hip Disease. The patient was eight years of age; the disease was of four years' duration. When the lumbar spine is straight, as in the figure, the angle of flexion at the hip becomes evident. (Original.)

But careful examination will show that there is very definite restriction of movement at this early stage. The restriction, however, takes place at the extreme limits of the arc of motion. Thus we find that full extension is impossible if a definite amount of flexion persists; the degree of this is determined by the methods already alluded to; full flexion on the abdomen is also impossible. So is it also with extreme adduction or full abduction; these movements are resisted. Similar observations may be made regarding the move-

ments of rotation. The resistance offered to these various movements is produced by muscular contraction.

In later stages of the disease, when the symptoms are more acute and considerable damage to joint structure has occurred, the attitude of adduction and flexion may be rigidly preserved by tonic contraction of the muscles, and any attempt to alter the position of the limb is promptly resisted by reflex

FIG. 266.—The Same Patient as in Fig. 265. The picture illustrates lordosis of the lumbar spine when the patient is standing upright upon the affected limb. (Original.)

muscular spasm. Under an anæsthetic these movements may be carried out much more freely, the resistance being greatly diminished when the limb is examined under these conditions. In the absence of anæsthesia any attempt to force the limb from its assumed position results in movements of the pelvis along with the femur, movements which are made for the purpose of preserving the angle of flexion and adduction. These movements of the pelvis, while passive

manipulation of the limb is being carried out, are dependent upon the sensitiveness of the diseased hip joint and must be eliminated in our estimation of the actual amount of movement possible at the hip joint.

At this later period of the disease there may exist actual mechanical resistance to movement, as, for example, in dislocation on to the dorsum ilii, or there may be fibrous or osseous ankylosis to account for rigidity. In ankylosis the limb may be fixed in a faulty position in cases that have not been cared for during the earlier stages of the disease; Figs. 265, 266, and 283 illustrate cases of this kind. In Fig. 266 it is observed that the limb can be brought to the ground for purposes of support only by tilting the pelvis and arching the lumbar spine.

Atrophy of the Limb.—The atrophy of the muscles of the limb is an essential accompaniment of tuberculous arthritis. This is noticeable both in the gluteal region and in the thigh and leg. Circumferential measurements will indicate the degree of atrophy present in the thigh and leg, and the flattening of the buttock is also largely produced by muscle atrophy. It would appear that the muscle atrophy is more marked in synovial disease, but it occurs in all joints affected by tuberculous disease. The cause of muscle atrophy is discussed elsewhere (page 583); failure of nutrition producing atrophy is probably mainly due to some reflex nervous influence. This failure of nutrition is also to be observed in the bone, which, in advanced disease, is atrophied often to an extreme degree (see Fig. 249 and Fig. 290). In the late stages of the disease, and particularly when ankylosis is present, disuse is undoubtedly an important factor in the production of atrophy. Comparative measurements here, too, will show increased disparity between the two limbs because of the hypertrophy of the sound limb caused by the increased amount of work thrown upon the muscles of the sound side. The atrophic condition of the muscles is frequently very readily appreciated by handling the limb, when the atrophied muscles are obviously in a flabby condition as compared with those of the sound limb. The nutrition of the skin is also impaired and becomes thinner than normal.

Shortening of the Limb.—In the early stages shortening of the limb is not present, but it is a very constant condition after the disease has progressed for any great length of time. The disparity in length of the two limbs in an individual who has suffered from hip-joint disease is due, on the one hand, to pathological changes at the joint, which bring about actual shortening, and, on the other hand, to arrest in growth (in length) on the affected side while the sound limb lengthens and thus increases the disparity between the two. The pathological changes at the joint which lead to shortening are chiefly those causing absorption and disappearance of the head of the bone, with changes in the neck, resulting in shortening of the neck and an alteration of the angle which the neck forms with the shaft; this angle is reduced in disease; further,

the alteration in the shape of the acetabulum, permitting the changes which, when extreme, constitute complete dislocation of the head on to the dorsum ilii. In rare cases it is said that the acetabulum has been perforated and the shortened head and neck have passed through into the pelvis, thus increasing the shortening. Short of actual perforation, the acetabulum may be sufficiently eroded and deepened to cause diminution in the length of the limb. Then, too, the epiphysis separating the head from the neck may be destroyed and cause arrest of growth in length at this point, resulting in diminished length on the diseased side as compared with the sound side. Lastly, the failure in nutrition of the whole limb would necessarily affect the growth in length of the affected side and would cause the limb to remain shorter than its fellow. The foot may participate sufficiently in this failure of nutrition to show a marked degree of shortening and diminished size.

In taking measurements of the length of the limbs it is important to see that the two limbs are in exactly the same position as to flexion, abduction, etc.; otherwise the results obtained will be erroneous.

The amount of shortening due exclusively to changes at the seat of disease in the hip may be estimated apart from that due to interference with the growth of the limb. Nélaton's line may be used for the purpose; a line is drawn from the lowest point of the anterior superior iliac spine to the most prominent point on the lower and posterior surface of the tuberosity of the ischium. Under normal conditions the tip of the trochanter will touch this line, but when there is shortening the trochanter will come to lie at a higher level, and the amount of shortening so indicated will represent that due exclusively to changes at the hip. This may be compared with the shortening of the entire limb, which may be ascertained, as already indicated, by measurement from the anterior superior spine of the ilium to the internal malleolus. Another method of estimating the shortening due to changes at the hip is by determining the relative distance of the trochanters from the middle line of the body. This may be done by using calipers for the purpose. It must be noted, however, that if true dislocation has occurred on to the dorsum ilii, the trochanter on the diseased side may not be nearer the middle line than its fellow.

Koenig, in estimating the frequency of shortening as a result of hip disease, found that it existed in 52.1 per cent of his cases. Where resection had been resorted to, there was shortening in 69.4 per cent of the cases; while where conservative treatment had been adopted, the percentage of cases in which shortening occurred was only 36.1. These figures are, however, not necessarily in favor of conservative treatment, because the conditions which made resection advisable, in all probability induced a greater degree of shortening. Koenig's observations were made by measuring the height of the trochanter in relation to Nélaton's line. Apart from these considerations, however, there can be no doubt of the fact that the best functional result is attained by conservative

treatment, and resection must be resorted to only when demanded by conditions which will be discussed in the section on treatment.

It is quite impossible to state the degree of shortening which remains permanently in individuals who are the victims of hip disease. The greatest disparity in length of the two limbs is, of course, possible where the disease occurs in the young growing child, because the development of the diseased limb does not keep pace with that of the healthy one. It also obviously depends on the amount of destruction of the bones at the hip, and the possible displacement of the head of the femur from the acetabulum. The extremes may be suggested by stating that as much as five or six inches of shortening has been recorded as the final and permanent result of hip disease; it is rare to have shortening to such an extent, however, and, fortunately, a large proportion of our patients recover without any shortening whatever.

Lengthening of the Limb.—Real lengthening of the limb occurs as a rare manifestation of disease at the hip. It simulates a condition which is much more common as the result of disease at the knee joint. The cause of real lengthening may be found in an increased activity of growth at the epiphyseal cartilage; this increased activity may be induced by the hyperæmia which affects the tissues in the neighborhood of the tuberculous focus. It is also suggested that the formation of diseased tissue in the bottom of the acetabulum may force the head of the bone downward, and thus bring about a certain amount of lengthening of the limb.

Abscess.—The occurrence of chronic abscess in tuberculous hip disease is frequent. Koenig's statistics of 568 cases showed that abscess occurred in 321, *i.e.*, 56.5 per cent of the patients. The position of the abscess was recorded as follows:

On the inner side of the thigh (limited toward the outer side by the femoral vessels)	26 cases
On the anterior aspect of the thigh (limited externally by a line drawn vertically through the anterior superior iliac spine)	126 "
On the outer side of the thigh (in the region of the trochanter)	63 "
On the posterior aspect of the thigh	49 "
In the pelvis	41 "
Situated over the pubis	5 "
Large abscess surrounding the thigh or passing down the thigh toward the knee	4 "
Cases in which the location was not stated	7 "

From these statistics it is obvious that an abscess on the anterior aspect of the thigh is much more common than elsewhere, and that such is the case is proved by general observation. The age of the patients in whom abscess formation occurs has also been noted by Koenig, and his results may be tabulated as follows

Age.	No. of cases observed.	No. of these cases in which abscess occurred.	Percentage of occurrence.
0– 5	103	62	60.2 per cent
5–10	167	95	56.9 "
10–15	116	68	58.6 "
15–20	93	43	46.2 "
Over 20	73	44	60.3 "
Age not recorded	16	9	56.2 "

From these statistics it is obvious that the tendency to the formation of a chronic abscess is shared fairly evenly by individuals at all ages. From fifteen to twenty, however, there is the greatest degree of immunity, while at the extremes of life the tendency to abscess development is most marked.

The clinical signs indicating the formation of an abscess are those of a fluctuating tumor in one of the localities mentioned about the diseased hip. The origin and course of these abscesses have already been discussed (page 630), and the pathology has also been described (page 580). There may be no warning whatever of the formation of the abscess, and its existence may be discovered in a purely accidental fashion. It thus becomes important to examine patients under treatment in a routine manner from time to time for the purpose of determining whether or not an abscess is forming. Not only is it necessary to examine the region of the thigh about the hip, but the iliac fossa must be palpated, and, if necessary, a rectal examination should be made if one suspects the existence of an abscess in the true pelvis. By digital examination through the rectum one can determine a thickening of the tissues, or the presence of an abscess in the region of the acetabulum. While the onset of abscess formation may thus be insidious, yet in acute cases and particularly where the patient is not being properly cared for, there may be much pain and other serious symptoms attendant upon its formation. Pain, elevation of temperature, and increased muscular spasm may be present, and abscess formation may be found to be the cause of this exacerbation of acute symptoms.

As long as the abscess remains of a purely tuberculous nature the course of the disease may not be influenced by its formation, but the great danger is mixed infection, and if this occurs the case at once assumes a much more serious aspect, and the chance of securing and maintaining functional efficiency of the joint is greatly lessened because extensive destruction of joint structure is commonly the result of such mixed infection. A purely tuberculous abscess may be efficiently dealt with by operative means, as we shall see, but once mixed infection has occurred, then we have, as a result, discharging sinuses which may persist for long periods, and the patient suffers from the usual sequence of events which supervenes from long-continued suppuration; there is failure of the general nutrition, with, later on, visceral amyloid disease and possibly fatal results. This train of symptoms often has its inception in the formation of a chronic

abscess, and the unfortunate results may often be prevented by early detection of the abscess and by the employment of efficient treatment soon after it begins to develop. A case illustrating the existence of many sinuses and of extensive joint destruction is shown in Fig. 267, which represents a lad of fourteen who had had discharging sinuses for ten years with ankylosis of the hip in a position of flexion and adduction.

Fig. 267.—Tuberculous Disease of the Hip Joint. Ankylosis in faulty attitude of Marked Flexion and Adduction, with numerous discharging sinuses. The patient was fourteen years of age and had suffered from trouble in the hip for ten years. (Original.)

Localized Swelling.—There may be some fulness, particularly on the anterior aspect of the thigh, about the hip. This may be due to infiltration of the tissues about the joint, and is most frequently appreciable in synovial disease where the ligaments have become the seat of inflammatory swelling. Fulness about the hip may also be due to abscess formation.

Constitutional Symptoms.—The constitutional manifestations in hip disease vary within wide limits. The symptoms are often so slight as to avoid detection altogether. The temperature may be slightly elevated, but this is seldom the case except where marked indication of an acute process is evidenced in the local trouble. Where the disease is getting progressively worse there is failure of general nutrition, but it is often difficult in such cases to distinguish between cause and effect. It may be that a lower state of vitality and diminished power of resistance are accountable for the fact that certain individuals fall easy victims to the disease, once infection occurs. On the other hand, the local disease may react upon the individual so as to impair his general health. Pain may interfere with sleep, and, in certain cases, confinement to bed and the impossibility of taking exercise in the open air may result in general nutritional disturbance with loss of flesh and general malaise. Marked constitutional effects are produced when mixed infection occurs in a tuberculous abscess, so that, while such an abscess remains unopened, there are elevation of temperature, quickened pulse, and other indications of septic absorption.

Diagnosis.—Systematic and careful examination of the hip must be carried out in order to determine the existence or otherwise of the local manifestations of disease which have been described. A patient the subject of hip disease, seeking advice, may not refer the trouble to the hip at all, but may imagine that it is located elsewhere; the most notable example of this is where the pain is referred to the knee. Examination of both joints in such cases will show that the knee is healthy, while disease in the hip will become manifest. It is important to note the attitude assumed by the patient while standing and walking as well as that maintained when he is lying down. The comparative length of the limbs and the circumferential measurements must be ascertained. Real shortening is determined by measuring from the anterior superior iliac spine to the internal malleolus or by ascertaining the relative height of the trochanter major in relation to Nélaton's line. Apparent lengthening or shortening is found by measuring from the umbilicus to the internal malleolus. In taking these measurements it is necessary to make sure that the sound limb has not previously been the seat of disease or of injury; under such circumstances it is useless for comparison. Fig. 286 illustrates the case in point; it is that of a child suffering from hip disease of the left side with knee trouble on the right side. Neither side would give us normal measurements. Occasionally there is double hip-joint trouble, to complicate matters. Where trustworthy comparative measurements are not available we must rely on other means for establishing a diagnosis. In order to determine faulty attitude the patient should be made to lie upon a flat and firm surface such as a table or a firm mattress; there must be no yielding to pressure of the surface upon which he lies. The degree of flexion, abduction, etc., may then be determined by the methods already referred to. It may be noted here that when the angle of flexion is very small it may best be appreciated by placing one's hand, with its dorsum on the table, under the patient's back in the lumbar region, and then causing the patient to flex first the sound and then the diseased limb at the hip. When the sound limb is flexed, no increased pressure is appreciated on the hand; but the moment the diseased limb is flexed, one immediately appreciates pressure upon the hand in the loin. The slight amount of lordosis which exists is obliterated whenever the diseased limb is flexed, but it is preserved while that limb is extended; hence the explanation of the increased pressure of flexion. The existence of tuberculous disease elsewhere or a strong family history of tuberculosis would suggest the nature of one's diagnosis, but it must be remembered that hip-joint disease is often a purely local manifestation and may occur in individuals otherwise apparently healthy.

The *x*-Ray as an Aid to Diagnosis.—This may be of great value in individual cases by giving us positive information of disease. On the other hand, negative results do not by any means exclude the existence of a tuberculous focus. A skiagram is best studied by viewing the photographic plate by transmitted

light. These plates, when reproduced in the form of a print cannot give the fineness of detail which is appreciated in a well-illuminated *x*-ray negative. The illustrations here given in Plate XXIV, Figs. 1 and 2, indicate the kind of information which may be derived from a skiagram. The patient was a lad fifteen years of age, who for six months had complained of slight pain in the left hip and lameness. These conditions were not constant, but intervals of freedom from all discomfort occurred. Examination disclosed a slight degree of atrophy, with some restriction of movement, but no appreciable shortening. The skiagram showed a tuberculous focus in the upper part of the left femoral neck, with very noticeable shortening of the neck; the head of the bone and the acetabulum were normal and there was no evidence of disease in the synovial membrane. The diagnosis here was made of a localized deposit in the neck of the femur. With rest and appropriate treatment the lad recovered. It is essential in these cases, if we are to get the maximum benefit of this method of diagnosis, to prepare two plates, one of each side, and thus be able to compare the diseased side with the normal side. In Plate XXIV this comparison may be made. In tuberculous affection of the bones and joints the *x*-ray picture may demonstrate, among other things, atrophy of the bone (Plate XXVI and Fig. 290), abscess in bone (Fig. 254), the existence of a sequestrum (Plate XXV), and loss of a well-defined contour of the articular extremities of the bones entering into the joint structure (Figs. 253 and 290). It must be remembered that an old, healed tuberculous lesion may show up in the radiogram. The *x*-ray method of examination has been used as a means of studying the progress of these cases and for determining the effect of our therapeutic measures (Freiberg). The *x*-ray must therefore be looked upon as of positive value in diagnosis, but we must remember that it is merely an important adjunct to careful clinical methods of examination which must not be neglected in any detail.

Tuberculous disease at the hip may be confounded with other affections, and we may now observe certain points in differential diagnosis which are worthy of note.

Injury to the Hip.—Injury may be the starting-point of actual tuberculous disease, and this fact must be borne in mind in the individual cases which come under observation. Synovitis may result from traumatism, or there may be congestion in the osseous tissue; the muscles, too, about the joint may be strained or bruised. The local signs of trouble usually supervene almost immediately after the injury. The disability present may closely simulate hip-joint disease, and an immediate positive diagnosis may not be possible. Such cases must be kept under careful observation in order to establish an accurate diagnosis; in the absence of tuberculous trouble the symptoms will usually disappear after rest in bed for a few days.

Fracture of the Neck of the Femur.—Whitman has shown that fracture of the neck is much more common in children than has hitherto been supposed.

EXPLANATION OF PLATE XXIV.

The radiograph illustrates tuberculous disease in the left hip joint. There is considerable shortening of the neck of the femur, as is evident when one compares the diseased side (Fig. 1) with the sound side (Fig. 2). The head of the bone and the acetabulum appear normal, but a tuberculous deposit is seen in the upper part of the neck of the femur. The patient was fifteen years of age and had complained of slight pain in the left hip for six months previous to observation; lameness manifested itself in an intermittent fashion; during the intervals he suffered no disability. Examination showed the characteristic muscle atrophy in the limb and limitation of movement. Under appropriate expectant treatment the patient recovered.

The *x*-ray picture was reproduced by Dr. S. Cummings, of Toronto, under whose care the patient was treated and to whom the author is indebted for both the photographs and the history of the case.

Fig. 1

Fig. 2

RADIOGRAPHS ILLUSTRATING TUBERCULOUS DISEASE IN THE HIP-JOINT IN A PATIENT 15 YEARS OF AGE

The fracture is usually of the green-stick variety, without separation of the fragments, but with change in the angle of the neck. Often the patient is able to get about and use the limb soon after the injury, but he suffers pain and discomfort. When this condition exists, it is frequently mistaken for early and acute hip-joint disease. It will be found on inquiry that the disability followed immediately after the accident. Measurements will show a certain degree of shortening; the trochanter lying at a higher level than normal, and the muscles on guard contracting to protect the injured joint. The *x*-ray here may be utilized to establish the diagnosis.

Coxa Vara.—In this condition there is sometimes an abnormal curvature of the femoral neck, producing a marked rotation outward, elevation of the trochanter major, and shortening of the limb. The neck of the femur is generally bowed forward, and an unusual degree of rotation outward is often possible, to such an extent in some instances that the patella looks almost directly outward. While certain of these conditions might suggest hip disease, it is soon evident on examination that tuberculous arthritis can be excluded. In these cases there is no history of the earlier manifestations of hip trouble. Then, too, complete extension is usually possible, while the reverse is characteristic of a tuberculous hip. There is an absence of the usual indications of disease in the joint. The less marked cases of coxa vara, where there is limitation of movement in flexion and in abduction, are sometimes mistaken for early hip-joint disease.

Congenital Dislocation of the Hip.—Confusion can hardly occur here if careful examination is made. The lameness from which the child suffers has been present from the time when the child began to walk, and there is an entire absence of the local signs of disease.

Acute Osteomyelitis.—The sudden onset here of acute symptoms, with high fever and the early formation of an acute abscess, is in marked contrast with the usual insidious appearance of tuberculous disease. Acute epiphysitis at the hip runs a very rapid course, with grave constitutional disturbance manifesting itself often after one of the acute infective fevers; the patient is obviously very ill from the beginning of the trouble, and destructive changes proceed rapidly. A recognition of these conditions will prevent confusion with tuberculous disease.

Gonorrhœa and Syphilis.—Gonorrhœal arthritis may simulate hip disease when it occurs in the adult. Here, again, sudden onset is at variance with tuberculous trouble, and the history of the case will throw light upon the condition. In infants, gummatous epiphysitis may occur as a manifestation of congenital syphilis. It is rare, but has been noted as simulating hip disease. Localized swelling is present, and the trouble in the hip is accompanied by other manifestations of syphilis elsewhere in the body.

Scurvy.—In scurvy the pain, tenderness, and swelling about the joints may

simulate hip disease. It is rare, however, that the inflammation is confined to one joint; and when it is so, it is usually the knee rather than the hip. The possibility of scurvy being the cause of joint trouble should, however, be borne in mind, particularly in infants artificially fed.

Rheumatism.—Monarticular rheumatism in the adult or in the young child may occur, but the disease is seldom long confined to one articulation, and thus differs from hip disease. Difficulties in diagnosis may, however, be so marked that it may be impossible to make accurate differentiation between the two conditions. The case may become clear under continued observation, as, for example, through the effect of appropriate remedies in rheumatism. In old patients rheumatism is much more common as a joint affection than tuberculous disease. "Growing pains" in a child are commonly looked upon as of rheumatic origin and the symptoms are not infrequently referred to the hip. These symptoms, however, are, usually very evanescent, and are not likely to be confounded for any length of time with hip disease.

Arthritis Deformans.—In this so-called "rheumatoid arthritis" grating is observed as an early symptom, and irregular ossified outgrowths may occur about the articular ends of the bones. While the hip joint may remain throughout the only joint affected in this disease, yet, as a rule, other joints become involved sooner or later. Old people are the more likely victims, but the disease also occurs in childhood occasionally. The diagnosis is sometimes difficult in the adult, and the x-ray is of service in helping one to determine the true condition present.

Sacro-iliac Disease.—This affection is rare in children; it is quite common in adults. Pain on pressure over the diseased articulation, with absence of pain at the hip, may be determined. Movements at the hip joint may be carried out freely when the pelvis is fixed. Measurements will reveal a normal relation of the trochanter major to Nélaton's line, and other evidences of disease restricted to the hip are absent. Apparent lengthening on the side of the disease is sometimes present. Pain is manifested in a characteristic fashion when the ilia are grasped by the two hands anteriorly and rocked from side to side or pressed together while the patient lies upon the back. The x-ray has proved serviceable in establishing a diagnosis.

Spinal Disease.—The existence of disease in the lower lumbar spine is not infrequently confused with hip disease. The reason is because the pain in this affection is often referred to the lower limb. Further, the muscles attached to and associated with the movements of the spine are the seat of spasm. This involves the psoas muscle, which, by its contraction, may produce flexion at the hip joint to such a degree as to simulate hip disease. The psoas would not, however, cause external rotation, as erroneously stated by some, as the muscle, when in action, is an internal rotator. The psoas contraction in disease of the lumbar spine is usually bilateral, but not always so. Careful examination of

EXPLANATION OF PLATE XXV.

The radiograph illustrates tuberculous disease in the right knee joint. The femur and the fibula are apparently healthy, but the inner part of the epiphysis of the tibia has been destroyed and a large sequestrum is seen in that locality. The radiograph of the diseased knee (Fig. 1) may be compared with that of the sound side (Fig. 2). The patient was ten years of age and had suffered from trouble in the knee for a year before the *x*-ray picture was taken. There were marked enlargement of the joint and flexion deformity. The tumefaction had increased very much for a month before the skiagraph was made, and an abscess had opened over the inner tuberosity of the tibia. There was marked infiltration of the synovial membrane. At an operation performed upon the joint the accuracy of the conclusions arrived at from the study of the radiograph was confirmed.

The *x*-ray picture was reproduced by Dr. S. Cummings, of Toronto, under whose care the patient was treated and to whom the author is indebted both for the photographs and for the history of the case.

Fig. 1

Fig. 2

RADIOGRAPHS ILLUSTRATING TUBERCULOUS DISEASE IN THE KNEE-JOINT IN A PATIENT 10 YEARS OF AGE

the hip will enable one to exclude hip disease without much difficulty, but in young children it may be exceedingly difficult to differentiate. If the thigh is flexed on the abdomen so as to relax the psoas muscle, then, in the absence of hip disease, the movements at that joint are unrestricted. This is a very useful method of examination in these cases.

When psoas abscess exists as a result of spinal disease, and when the abscess extends down below Poupart's ligament, we get, on the antero-internal aspect of the thigh, a fluctuating tumor which may be mistaken for an abscess having its origin in the hip. If such an abscess were the result of hip disease we would expect indications of trouble in the hip of a marked character, with elevation of the trochanter major and other evidences of destructive changes in the joint. These, however, are absent in spinal disease.

Affections of Bursæ about the Hip.—The ilio-pectineal or the trochanteric bursa may become inflamed and cause a painful fluctuating swelling in the one case on the anterior aspect of the hip, and in the other posteriorly. Conditions of this kind may be mistaken for abscess connected with hip disease, but careful examination shows that the essential signs of hip disease are wanting.

Tumor.—A new growth such as a sarcoma may involve the tissues about the hip and produce a painful swelling, with limitation of movement. The character of the enlargement and the history of its development will usually be sufficiently characteristic to exclude hip-joint disease.

Sciatica.—An error in diagnosis is not infrequently made in confusing sciatica with hip disease. In the latter, however, the limitation of movement, with muscle spasm, is present. In sciatica pain extends down the back of the thigh and the leg, and tender points may often be detected on pressure along the course of the nerve. Complete flexion at the hip will usually produce much pain in sciatica by stretching the hypersensitive nerve.

Hysteria.—Pain in the hip joint and faulty attitude, with lameness, may occur in a hysterical subject, and hip-joint disease may be simulated. These patients usually present other symptoms of hysteria, and examination of the limb shows that muscular atrophy and muscular spasm are absent. There is also entire absence of shortening or other indications of a destructive lesion of the joint structures.

Infantile Paralysis.—At the onset of this disease there may be pain in the hip, but it is suddenly developed and usually is accompanied by a history of febrile disturbance. When the paralysis develops, as it will do at all events in a few days, the diagnosis is apparent.

Inflamed Lymph Nodes in the Groin.—Such inflamed nodes may produce a painful swelling at the hip, and cause the patient to assume an attitude of flexion while movement at the hip is resisted. These inflamed nodes are, however, easily palpable, and a normal joint is found on examination. Other painful conditions in the region of the hip, or the lower part of the abdomen, may

similarly cause the patient to assume an attitude of flexion at the hip in order to relax the fascia at the groin. For example, appendicitis has been mistaken for hip disease, but an examination locally and the history of the development of the case will enable one to establish an accurate diagnosis.

Complications.—Reference has been made (page 566) to the fact that tuberculous arthritis may supervene in a patient who is already a victim of tuberculous disease elsewhere. Thus hip disease may occur in one who is suffering from pulmonary tuberculosis. The reverse order of events may, however, take place, and the subject of hip disease may develop tuberculosis in some other part of the body; occasionally this fresh development is obviously derived directly from the primary focus of disease in the hip. The most notable instance of this is where tuberculous meningitis manifests itself in hip disease. Occasionally, too, a patient who suffers from a purely localized lesion in the hip becomes a victim of disseminated miliary tuberculosis. These secondary manifestations of tuberculosis have in some cases a direct relation to some suddenly induced activity in an old tuberculous focus which has become quiescent. Thus it appears that the breaking down of adhesions in a joint which has become ankylosed during the progress of disease in the hip may be followed by tuberculous meningitis or disseminated miliary tuberculosis.

A complication the importance of which cannot be exaggerated is that which occurs as the result of mixed infection of an abscess which is primarily a purely tuberculous lesion. The serious and often fatal results which may follow mixed infection are frequently preventable; hence the importance of recognizing this complication of tuberculous arthritis. The appropriate methods of dealing with a tuberculous abscess have been discussed elsewhere, but here we wish simply to narrate the sequence of events which are likely to follow mixed infection. It is usually a staphylococcus infection which supervenes, and, when this occurs, the whole aspect of the case is changed; destructive processes make havoc of the joint structure, and complete disintegration of the articulation may occur. It is, however, continued suppuration which soon produces constitutional effects, and we frequently have a familiar train of symptoms occurring in these cases. General toxæmia is induced, and as a result there is failure of nutrition, with emaciation; visceral disease manifests itself, with amyloid degeneration of the internal organs. Finally, the patient may die of exhaustion. While these results are fortunately not always reached where mixed infection occurs, yet they are sufficiently frequent to put us on our guard and to induce us to exercise the most scrupulous care in using efficient prophylactic measures where they are at all practicable.

There are certain complications which are produced more or less by mechanical means in the course of hip disease of long standing. Thus, there may be permanent changes in the lumbar spine where extreme lordosis has been long maintained, so that permanent deformity may result. Similarly, lateral

EXPLANATION OF PLATE XXVI.

The radiograph illustrates tuberculous disease of the ankle joint and tarsus. It will be seen that the disease has involved the ankle joint and has caused considerable destruction of the lower end of the tibia and of the astragalus. The other bones of the tarsus show a marked condition of rarefying ostitis, the normal architecture of the cancellous tissue is lost and is replaced by a diffuse, somewhat blurred shading, while the surrounding layer of compact tissue shows up as a delicate tracing, as if it were pencilled in with clear definition. These characteristic appearances are at once appreciated when one compares the radiograph of the diseased foot (Fig. 1) with that of the sound foot (Fig. 2). The patient was twenty years of age and, about six months before the radiograph was taken, suffered a severe sprain with, probably, rupture of some of the ligaments. The usual signs of tuberculous infection subsequently developed. The foot was amputated, and the accuracy of the conclusions arrived at from a study of the radiograph was confirmed.

The *x*-ray picture was reproduced by Dr. S. Cummings, of Toronto, under whose care the patient was treated and to whom the author is indebted both for the photographs and for the history of the case.

FIG. 1

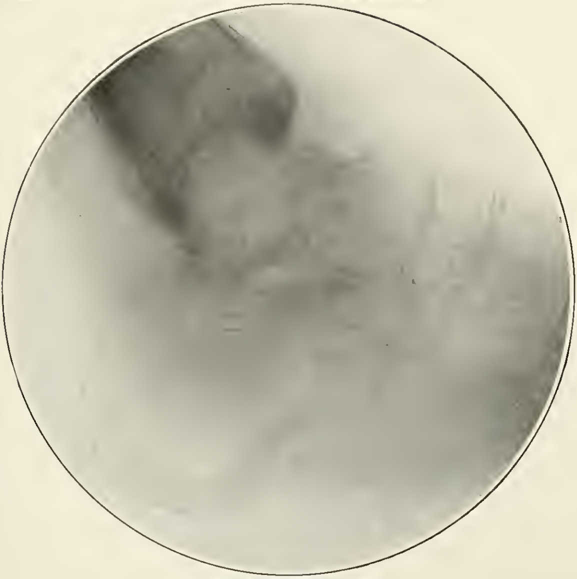

FIG. 2

RADIOGRAPHS ILLUSTRATING TUBERCULOUS DISEASE OF THE ANKLE-JOINT AND TARSUS IN A PATIENT 20 YEARS OF AGE

curvature after persistent adduction may result in permanent spinal deformity. In the knee, too, long-continued adduction may produce knock-knee. Genu recurvatum results from a laxity of the ligaments about the knee joint, produced apparently by continued rest in the recumbent position. Lastly, talipes equinus may result from permitting the foot to be drooping and unsupported while walking with a splint so constructed as to prevent the weight of the body being transmitted through the diseased limb, while the opposite limb is supported on a boot with a high sole and heel. As a rule, most of these deformities can be prevented by suitable treatment.

Prognosis.—This must be considered from two aspects, namely, with reference to the functional result obtained as far as the joint is concerned, and with reference to the mortality attendant upon the disease. Hip-joint disease is to be considered a serious affection, and the prognosis must be always guarded, as it is impossible to predict the outcome with any degree of positive assertion in the individual case. The disease is a local manifestation of tuberculosis, and as such is classified as a form of "surgical tuberculosis," the course of which is usually favorably influenced by local treatment. The constitutional state of the patient must, however, react upon the local trouble, and so we find that morbus coxæ, developing in a sickly infant, is a much more serious matter than when the health is good and the general nutrition well preserved. Similar conditions influence the course of the disease at any age. A strong family history of tuberculosis also has a definite and unfavorable bearing upon the prognosis. These considerations are discussed at length in the earlier part of this article, under the heading of Prognosis in General (page 584). The existence of a tuberculous lesion elsewhere in the body is presumptive of a low power of resistance to the inroads of the bacillus, and the outlook is bad in such cases.

The prognosis is materially affected by the formation of an abscess, and particularly so when mixed infection occurs. In these cases not only is there evidence, in the abscess formation, of destructive processes of an extensive character, but there is at once instituted a menace to the general health as the result of absorption from the infected abscess. Constitutional disturbance occurs with failure of nutrition, the internal organs become diseased, albuminuria is likely to supervene as the result of amyloid disease of the kidneys, and so the case may progress to a fatal termination along such lines. The destructive processes which continue in the joint in these cases will greatly diminish the possibilities of a good functional result should the patient recover.

The *mortality of hip disease* is variously estimated by different observers. The difficulties in producing accurate statistics are great, because of the fact that the cases must be followed for a number of years before a complete cure can be assured. The German surgeons place the mortality in hospital cases higher than do British or American surgeons. Thus, Koenig places the mortality at

40.3 per cent. In the Alexandra Hospital, London, the mortality in 384 cases was 26 per cent. At the Hospital for the Ruptured and Crippled, New York, Gibney reported 288 cases with a mortality of 12.5 per cent; Cheyne, of London, in his series of 77 cases had a mortality of 12 per cent.

The effect of abscess upon the mortality is striking; thus von Bruns, quoted by Whitman, found the mortality in non-suppurative cases to be 23 per cent, as compared with a mortality of 52 per cent in suppurative cases. Another valuable observation is with regard to the mortality in patients treated in private as compared with those treated in hospital clinics. This comparison is made by Whitman in quoting the following statistics: In 94 cases in private reported by Taylor (including 24 cases in which suppuration occurred) there were only 3 deaths. Sayre reported 212 similar cases with 5 deaths, and Lorenz 60 cases with 3 deaths. The logical conclusion is obvious, namely, that careful and efficient treatment has a marked effect on the progress of the disease, and the necessary conditions for securing the best results are difficult to fulfil in hospital practice.

A fatal termination, in hip disease, has been due to one of the following complications:

Tuberculous meningitis.
Amyloid disease.
Exhaustion.
Pulmonary tuberculosis.
Tuberculous peritonitis.
Acute miliary tuberculosis.
Septicæmia and pyæmia.
Shock following operation.
Intercurrent disease.

When hip-joint disease occurs in the adult the prognosis is worse than in the child, because, as a rule, the disease in the adult runs a more severe and destructive course than is the case in children. In some recent statistics published by Lewiasch from Kocher's clinic in Berne, 100 cases were reported. In 25 of these there was abscess formation with a mortality of 65 per cent. There were 75 cases without abscess, having a mortality of 13.3 per cent. Of those with suppuration 45 per cent of mortality occurred in children, while 80 per cent of mortality occurred in the adults. Of those without suppuration there was a mortality of only 8 per cent in children, and a mortality of 18.2 per cent in the adults.

The functional results obtained in the treatment of hip-joint disease necessarily vary with the extent of the disease and the efficiency of the treatment. When the case comes under observation at an early stage and treatment by rest and immobilization is adopted and efficiently carried out, recovery may take place with little, if any, restriction of movement, and almost perfect function is restored. The other extreme is where destructive processes have gone on to complete disintegration of the joint, resulting in fibrous or bony ankylosis, there being complete absence of mobility.

Efficient treatment is not only of service in restoring the normal function

EXPLANATION OF PLATE XXVII.

The radiograph illustrates tuberculous disease of the wrist. The patient was two years of age. The greater part of the carpus was cartilaginous; ossification had appeared only in two bones of the carpus, namely, the os magnum and the unciform, and in the lower epiphysis of the radius. The *x*-ray picture showed tuberculous invasion of these two carpal bones and of the proximal extremities of the second and third metacarpal bones. The characteristic appearances are at once appreciated by comparing the radiograph of the diseased wrist (Fig. 1) with that of the sound side (Fig. 2). The patient had exhibited signs of tuberculous affection of the right wrist for three months previous to the making of the *x*-ray picture. An operation was performed, and the accuracy of the conclusions arrived at from a study of the radiograph was confirmed.

The *x*-ray picture was reproduced by Dr. S. Cummings, of Toronto, under whose care the patient was treated and to whom the author is indebted both for the photographs and for the history of the case.

Fig. 1

Fig. 2

RADIOGRAPHS ILLUSTRATING TUBERCULOUS DISEASE OF THE WRIST-JOINT IN A CHILD TWO YEARS OF AGE

of the joint, as is happily the case in some instances, but, by appropriate means, deformity may be prevented, and, if a stiff joint results, the limb is fixed in a position which will subsequently be of most service to the patient. Shortening is inevitable if there is destruction of bone; flexion and adduction may, however, be corrected or prevented by appropriate mechanical apparatus. If the disease comes under observation at an early stage, then it will be necessary to maintain treatment for at least two or three years before a cure can be assured, even where satisfactory progress is made.

A slight degree of flexion may not cause much disability, but, when it amounts to more than thirty degrees, the impairment of function is marked. In extreme cases the joint may be fixed with flexion amounting to ninety degrees, and then much discomfort and disability results.

Such extreme flexion and too marked adduction often call for operative interference in an old-standing case with an ankylosed joint, but by such means a good functional result may still be obtained, the joint of course remaining stiff, but the deformity being corrected. In this connection it may be noted that much more disability occurs from deformity than from ankylosis.

The shortening which occurs in hip disease is not of itself a cause of great disability. In the absence of other deformity the effects of shortening can be overcome by wearing a boot with a high heel and sole.

In a series of 107 cases quoted by Whitman, as reported by Gibney from the Hospital for Ruptured and Crippled, New York, the following results were obtained: The patients were cured after mechanical and operative treatment. In many cases the disease was in an advanced stage, and deformity was present in more than half the cases when treatment was begun.

No flexion	47
Flexion of 10 degrees	30
Flexion of 10–20 degrees	20
Flexion of 20–30 degrees	10
Perfect motion was retained in	13
Good motion was retained in	22
Limited motion was retained in	41
There was ankylosis in	31

In 69 cases the shortening was one inch or less, 35 having no shortening. In 38 it was more than one inch.

The amount of shortening which is attained depends largely on the stage at which treatment is initiated. If efficient treatment is adopted early and maintained, there may be little or no shortening. Then, again, it should be noted that the growth and nutrition of the limb may be permanently damaged, so that, even after the disease has become quiescent, there may be an increase in the disparity in length of the two limbs, because the sound limb grows out of proportion to its fellow.

Conservative treatment affords the best prospect for good functional results.

Patients who have been treated by conservative methods recover with a more useful joint than those who have been subjected to operation. This broad statement requires some qualification in view of the fact that the conditions which demand operative interference are such that under any form of treatment marked disability would be the final outcome. The class of cases which we now submit to operation are those in which the lesions have been more than usually destructive to joint structure, and hence the degree of disability resulting must be proportionately greater. While the immediate result of an operation, such as an excision, may be to increase the amount of shortening to a slight extent, the object aimed at in its performance is to improve the local conditions so that a cure may be effected; the final result of operative interference in such cases therefore, if we attain our object, is to bring to an end the destructive processes which are actively progressing and thus minimize the amount of disability which would otherwise occur.

Early operative interference, such as was once advocated strongly, is not now entertained as a rational procedure because the functional result is not satisfactory; in this class of cases undoubtedly the best results are obtained from conservative treatment.

One exception may be made to the argument against early operative interference, and that is in the case of abscess formation, which may occur at any stage of the disease. Occasionally an abscess is best left alone, but at times operation is imperative in order that it may be got rid of before it reaches the surface, when mixed infection threatens. Such cases treated by appropriate measures, which will be described, are much more likely to yield a good functional result than when the abscess is allowed to attain large size and threatens to point upon the surface.

Treatment.—The principles to be observed in the treatment of hip-joint disease are in all essential details similar to those applicable to the treatment of tuberculous arthritis in any part of the body. In tuberculosis of the hip, however, we are seldom able to employ local operative measures for the eradication of limited foci of disease, measures such as are possible in other joints when the clinical signs, aided perhaps by an *x*-ray photograph, demonstrate a focus confined to a definite portion of the bone. The possibility of removing a focus of disease from the outer portion of the femoral neck will be referred to later, but, with this exception, operations of this nature are inapplicable to the hip; the peculiar structure, relations, and functions of this joint precluding the employment of such operative measures for relief. We are, therefore, forced to employ more conservative methods of treatment; the object aimed at is to secure for the diseased joint the best possible conditions favorable to spontaneous recovery. The satisfactory termination of a case of hip-joint disease depends upon the measure of success we attain in so raising the power of resistance of our patient that a cure of the disease is finally brought about.

Apart from the local measures we must see to it that the general health is improved by appropriate constitutional treatment; the importance of this cannot be overestimated. Satisfactory hygienic surroundings must be secured, the patient must live in the open air as much as possible, his room must be properly and efficiently ventilated, he must get suitable and nutritious food; exercise, so far as the conditions will permit, must not be overlooked. Certain remedies, such as cod-liver oil, the hypophosphites, arsenic, and the syrup of the iodide of iron are found useful in individual cases. The constitutional treatment has been discussed at length in the treatment of tuberculous joints in general (page 586), and a more extended reference is unnecessary here.

The so-called conservative treatment, if efficiently carried out, will do much to lessen the duration of the disease and to prevent the deformity and loss of function that invariably result in cases that have progressed and have been left untreated.

In untreated cases the time that must elapse before a natural cure is established is usually six or seven years, and at the end of that time the limb is in a position of marked flexion and adduction, with shortening to the extent of several inches as a consequence of tilting of the pelvis and the actual upward displacement of the femur, with destruction of the articular extremity to a greater or less degree. It may be considered fortunate, in fact, if the result in such untreated cases should prove as good as that just described. Very often the disease progresses to a still more unfavorable termination; in many instances, for example, the long-continued suppuration, common in neglected hip disease, induces amyloid degeneration in the viscera, and matters go from bad to worse until a fatal issue is inevitable. Efficient treatment in such cases as these would have shortened the duration of the disease by three or four years and probably suppuration would never have occurred, deformity would have been prevented, and the suffering which always accompanies the disease would have been lessened to a marked degree.

Too much stress cannot be laid upon the importance of an early diagnosis, for upon the stage in the progress of the disease at which efficient treatment is instituted depends the degree of success we attain in securing a good functional result. If the condition is recognized when the trouble is still confined to the bone, one may hope for a more or less complete restoration of the movement at the joint. But if the joint cavity has become involved with well-established erosion of the cartilages, the best result that one can hope for, by efficient treatment instituted at this stage, is ankylosis to a greater or less degree without deformity and with a minimum amount of shortening. If treatment has been delayed until actual upward displacement of the femur has taken place as the result of the absorption of bone or of a pathological dislocation, or until ankylosis in a deformed attitude has occurred, the best that can be done is to adopt measures that will lead to the eradication of what remains

of the disease as soon as possible, and then by operative procedure to correct or lessen the deformity.

The indications for treatment, therefore, depend upon the stage in the disease at which the case is first seen. In the acute stage one must relieve pain, prevent and correct deformity, and combat the tendency to shortening from erosion of cartilages and bone, and the greatest care must be taken to prevent the onset of suppuration.

The most efficient treatment is that which provides the most complete rest and protection for the affected joint. Obviously this can best be obtained when the patient is kept in the recumbent attitude. But when it is found that the pain has disappeared and the muscular spasm and the other local signs have pretty well subsided, it then is wiser to get the patient up, provided, of course, the surgeon has the means of securing ambulatory apparatus which will in an efficient manner secure the rest which is necessary for the joint while the patient goes about. The ambulatory treatment always has the advantage that the patient gets more exercise and more fresh air than when he is kept constantly in bed, and consequently the general health is much more likely to improve.

To provide rest for the diseased joint we have, along with recumbency, two very effective measures at our command, namely, splinting and traction.

The object of splinting is to prevent motion at the joint and so to guard the diseased cartilages and synovial membranes from injury that muscular spasm, now no longer necessary for protective purposes, will tend to disappear. The fixation of the affected part, too, will so protect the sensitive joint that the greater part of the irritation of the nerve endings in the joint will cease, and hence the reflex muscular spasm will be abolished. Theoretically, if we could produce perfect fixation this treatment would be all that is required, but as this is practically impossible the method sometimes fails.

Traction is a valuable adjunct to the treatment in that, by its proper use, muscular spasm can be frequently controlled. If a patient in the acute stage of the disease be put to bed with traction of about five or six pounds, gradually increased to ten or twelve pounds, the muscles soon become tired and the spasm is overcome. By this means the pain, which is due to the pressing of sensitive articular surfaces together as the result of contraction of the muscles, is prevented, and the faulty attitude which results from muscular spasm disappears. Examination of specimens of diseased hips, post mortem, shows that erosion of the cartilages takes place most extensively at the points of contact of the femur and acetabulum. Consequently, in cases where active disease is going on it is wise to lessen the pressure between the joint surfaces by traction and thus try to limit the amount of actual shortening which will result from destruction of bone and cartilage. In a series of experiments on healthy children Bradford and Lovett demonstrated that actual "distraction" of the joint

is possible under a steady pull of twenty pounds, and in diseased joints the amount of traction required diminishes with the amount of disorganization present.

Traction is made upon the limb by means of adhesive strapping, either of the moleskin or of the zinc-oxide variety, applied to each side of the limb, from the upper part of the thigh to below the knee. The strapping is cut into strips so that it will lie smoothly on the surface of the skin and in order that areas of skin may be left uncovered which may be used when the strapping is changed (see Fig. 268). At the lower end of each strap is a buckle into which fits the strap of a metal crosspiece which serves to spread the traction straps sufficiently to prevent injurious pressure on the malleoli. When the strapping has been applied, it should be covered with a cotton or flannelette bandage from the toes

Fig. 268.—The Method of Applying Traction Plaster to the Limb. (Original.)

to the groin and this bandage should be further secured by the application of stitches to the margins to prevent its being disarranged. To apply an extension apparatus in an acute case, the surgeon requires an assistant, who exerts gentle traction on the limb by grasping the heel and pulling in the line of the axis of the limb. Care must be taken to handle the limb gently in the application of the plaster and bandages. A point to be remembered is that the strapping must be applied high upon the thigh and not very far down on the leg, the reason being that if the plaster be mostly fixed to the leg, the traction on the hip is transmitted through the knee joint, and long-continued strain upon the supporting ligaments of the knee results in weakening and relaxation of that joint. When the strapping and adhesive bands have been satisfactorily applied, a rope, which runs over a pulley at the foot of the bed and to which is

attached the weight decided upon, is fastened to the metal crosspiece. To prevent the patient from being drawn down in the bed by the constant traction, counter-traction is provided by raising the foot of the bed or by passing beneath the perineum a padded band which is attached to the top of the bed.

Fig. 269.—The Long Plaster Spica used in the Treatment of Hip-joint Disease. (Original.)

Splinting may be provided by the use of a long plaster spica, extending from the mammary line down to and including the foot (see Fig. 269).

The most efficient treatment for acute disease is that which employs both splinting and traction. Frequently it is found that cases which do not respond to either method when used alone, are easily controlled when they are used together. By this means we have the benefit of both fixation and traction in relieving muscular spasm, the joint is protected from sudden motion by the splint, and the tendency to upward displacement from destruction of the cartilages and absorption of the bone is lessened by the traction.

The best manner of obtaining this valuable combination is by means of the plaster spica, put on over an ordinary adhesive-plaster extension applied to the thigh. After the adhesive plaster and bandages have been applied to the leg and thigh, the upper part of the thigh and the body are covered with seamless shirting or stockinette. The patient is now elevated upon a pelvic rest of the type shown in the photograph (Fig. 270), and, after the pelvic bones, the spine, and the front of the chest have been protected with one layer of silence cloth, a plaster spica is applied, extending from the ankle to the mammary line. Care must be taken to strengthen the plaster at the groin, as this is the part that is under the greatest strain. This may be done by making the plaster thicker at this point or by incorporating strips of basswood or even steel. An important point to be observed is to see that the buttock is completely covered in, only sufficient room being left between the edge of the plaster and the cleft

of the nates to prevent soiling of the plaster. This may be accomplished by making a small pad of plaster, about seven inches by five inches and about ten layers in thickness, and fastening it over the buttock by several turns of the bandage. The reason for this procedure is the necessity of providing a good posterior support and protection for the joint, and also of preventing the excoriation of the buttock that invariably takes place if the edge of the plaster is left opposite the gluteal fold, thus allowing the buttock to bulge out of the spica. When the spica is dry it should be covered with stockinette, which may

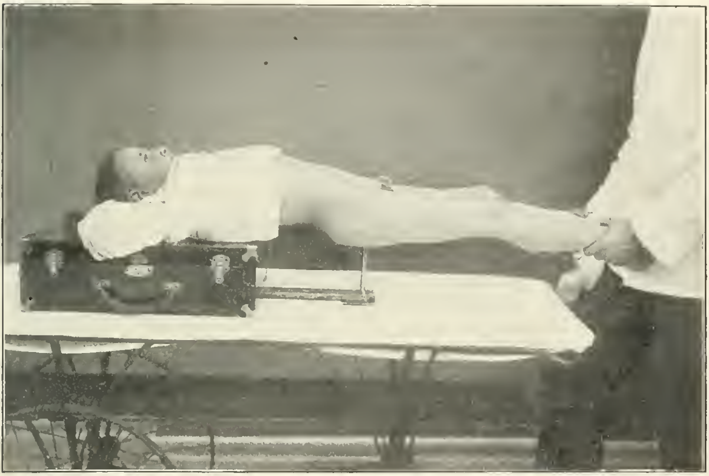

FIG. 270.—Pelvic Rest and Back Rest Employed for the Application of a Plaster Spica. A flat steel plate is applied to the sacrum at the end of the upright shown in the picture. The back rest here consists of a suit case into which the sacral support is allowed to slide on a horizontal bar. The case may be suitably furnished with plaster bandages, etc., and forms a convenient portable outfit for plaster work. The apparatus was devised by Dr. W. E. Gallie, of Toronto.

be changed in case it becomes soiled. In dealing with very small children, however, it is sometimes better to protect the area about the perineum with oiled muslin or by varnishing the plaster, in which case it may be washed. When the patient is put to bed, a weight of from five to fifteen pounds is applied. Within a few days the plaster in becoming dry loosens somewhat, and, later on, the leg shrinks a little; hence the importance of the traction is manifest. The traction is also of service in preventing the upward displacement of the spica. The grip that the plaster obtains on the bony points of the pelvis is never sufficient to oppose any considerable force exerted in an upward or downward direction, but it has sufficient grip upon the thigh and leg to be drawn down by the traction.

The above is the treatment advised for the very acute cases where night cries are frequent and pain severe. In cases, however, in which the symptoms are not so severe, less stringent measures are applicable. In these cases it is not necessary to fix the body above the pelvis; it is sufficient if the plaster extends from the ankle or from the knee to just above the crests of the ilia. In children who are not too fat and whose crests are fairly prominent, a most efficient spica may be applied in this manner, as is shown in the photograph (Fig. 271). This type of spica, commonly known as the short or Lorenz spica, has the advantage that it allows free movement of the spine while retaining nearly perfect fixation. As there is sometimes a tendency, on the part of the spica on the well side, to slip upward, it is customary to incorporate two

Fig. 271.—Short Plaster Spica Permitting Flexion at the Knee Joint. (Original.)

buckles fastened to pieces of perforated tin in the back and front of the plaster, and to attach to them a perineal band. By this device all tendency to adduction deformity is prevented.

For the less acute cases it is the custom in some hospitals to use traction alone, and, when the patient is in the hands of a competent nurse, the rest to the joint thus produced is fairly efficient. To prevent the flexion which occurs as a result of the sagging of the pelvis into the soft bed, the patient is made to lie on a hard, flat surface, the Bradford frame being the most convenient (see Fig. 272). To maintain a perfectly horizontal position and to produce a little fixation, a tie-down of the type shown in the figure may be used. The disadvantages of this treatment, however, are manifest, as in the majority of cases the patient moves about, and, in the daily changing of the sheets and using of the bed-pan, disturbance of the hip is unavoidable. It is the custom at the Hospital for Sick Children, Toronto, to put these less acute cases into a bed splint which was devised by Dr. W. E. Gallie and which is shown in the photographs (Figs. 273 and 274). It consists of a long outside bar of three-eighths-inch steel which is heavy enough to hold the hip and light enough to be bent to the attitude

of the limb. On it are three padded steel bands which encircle the chest, pelvis, and knee, and lower down there is a cup to support the ankle. These bands are sufficiently light to be bent to fit different-sized children, and by use of the thumb-screw, which fastens the bands to the bar, the splint is made adjustable in length also. A nice modification of this is to make a leather back for the splint, made by moulding it over a cast of the patient's back. The device at the bottom of the splint is for the purpose of retaining the traction undisturbed when the patient is moved about. The rope which connects the adhesive extension with the weight and pulley runs through a hole in the bottom of the splint, into which fits a clamp which can at any time be screwed down to catch the rope firmly. With perineal bands acting as counter-traction the limb is thus held firmly while the patient is lifted about or while a dressing is being done. One great advantage of this splint is that, by bending a portion of the longitudinal bar into a U, one can do a dressing in the region of the hip without removing the splint and without disturbing the limb. After the patient is put back to bed the weight is once more attached. Another device much used is the Thomas hip splint (Fig. 275). It consists of a posterior bar of light iron which is made to conform to the curves of the body, and to which are attached bands for the chest, thigh, and ankle, of sufficient lightness to be easily bent to fit the patient. The advantage to be claimed for this splint is that it can be made by any blacksmith, and, if necessary, by the surgeon himself. It is particularly useful where no orthopedic mechanics are available. A good modification of this splint is the one to which a pelvic band has been

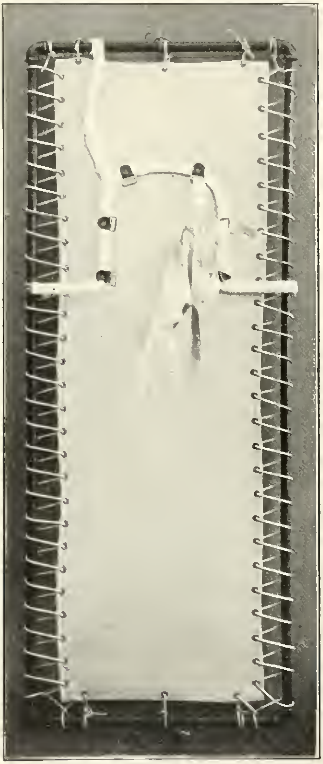

Fig. 272.—The Bradford Frame and "Tie-down." It consists of a steel frame to which is laced a canvas support for the patient. The "tie-down" consists of a piece of flattened steel which is fastened to the frame at the sides and at the top. The horizontal piece of this tie-down lies in the concavity of the patient's neck. To this, in turn, is attached, by means of straps, a piece of canvas which passes across the patient's chest, and by this means, combined with traction by strips of adhesive plaster applied to the limbs, the patient is effectually secured to the frame in a recumbent position.

added. This provides more perfect fixation to the joint. Traction of course can be used in conjunction with this splint.

Faulty Attitude due to Muscular Spasm.—In practically all cases of hip disease the question of how to deal with the early deformity arises. In even the very mild cases there is usually a slight amount of flexion, and in the severe cases this flexion may reach a right angle with considerable adduction and external or internal rotation. The primary cause of the faulty attitude is muscular spasm, the stronger group of muscles largely determining the attitude of the limb. If, however, the attitude of deformity is maintained for

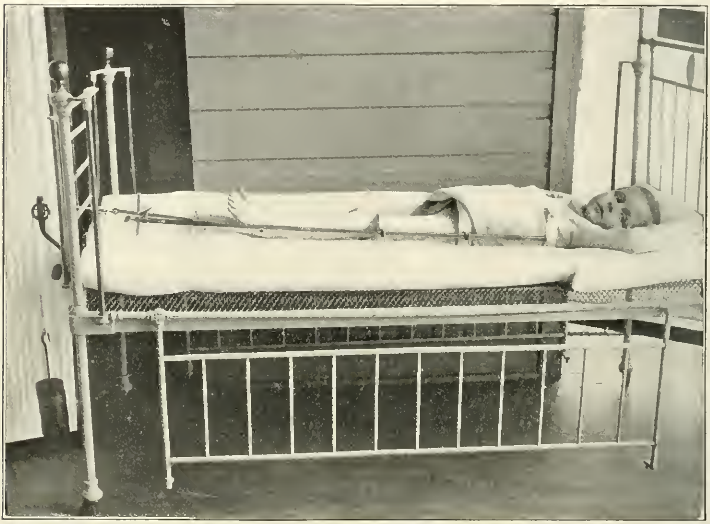

FIG. 273.—Bed Splint Devised by Dr. W. E. Gallie, of Toronto, for the Treatment of the Less Acute Cases of Tuberculous Hip Disease. (Original.)

several months, permanent contracture takes place in the muscle, the ligaments become shortened, and the inflammation about the joint causes the formation of adhesions. As a result it is necessary to apply considerable force in the form of leverage to reduce the deformity.

The treatment therefore devolves itself into two kinds—that which overcomes muscular spasm, and that which reduces the more fixed deformity.

Traction and splinting can both be used, and to advantage, in dealing with muscular spasm. If the former is to be employed, fairly efficient fixation can be obtained by fastening the patient's chest, pelvis, and leg to a steel frame of the type shown in the photographs (Figs. 276 and 277). It will be noticed that the leg is elevated until the lumbar spine lies flat upon the bed. The reason

for this is easily seen when the manner in which the psoas muscle is attached to the spine and trochanter minor is remembered. If the traction were applied in a line parallel with the bed, the thigh would be converted into a lever with the fulcrum at the trochanter minor, and the short arm between the trochanter and the joint. As a result the head of the bone would be forced more tightly into the acetabulum and the muscular spasm correspondingly increased. On the other hand, if the traction be applied in the line of the deformity, with the spine flat upon the bed, the leverage action is prevented and the traction simply expends itself in tiring the muscles and thus relieving the spasm. The

FIG. 274.—Gallie's Bed Splint for the Less Acute Cases of Tuberculous Hip. The illustration shows how the patient may be moved without disturbing the fixation and while extension is still maintained. (Original.)

ilio-femoral ligament may act very much as the psoas muscle in this particular. The neck of the femur in that case forms the short arm of the lever, and the fulcrum is at the point of attachment of the ligament to the anterior intertrochanteric line. Traction in the line of deformity produces much the same effect upon the ligament as upon the muscle; it is gradually stretched, and yields eventually to such an extent as to permit the flexion to be overcome.

The usual procedure is to put the patient into the traction frame which lies on top of an ordinary Bradford frame, and traction of about five pounds is then applied in the line of deformity. The weight is increased a pound a day for

a few days or a week, and then the leg is let down half an inch or so, until the lumbar spine just commences to rise. A few more days are allowed to pass and the same procedure is repeated. If the case is a suitable one for this form of treatment, all the deformity should be reduced in from two to three weeks.

Fig. 275.—The Thomas Hip Splint with Pelvic Band. It is fully described in the text.

If muscular spasm is to be combated by the employment of splinting alone, we again have recourse to the plaster spica. The patient is placed on the pelvic rest, with the thigh in the attitude of flexion. A spica is then applied, extending from the toes to the mammary line. In consequence of the fact that the thigh is necessarily flexed at the hip, one must see that the knee is also flexed so that the dorsal spine, the lumbar spine, the sacrum, and the heel of the affected side may be in the same horizontal plane. By this precaution we balance the patient properly in bed and obviate the necessity of any great degree of elevation of the bedclothes. After six or eight weeks have passed, this spica is removed, and in many cases it will be found that the deformity has already become considerably diminished. The explanation of this phenomenon is that, as the deformity is the result of muscular spasm, by removing the cause for muscular spasm by the complete fixation of the joint we have removed the agent which produces the deformity and consequently it disappears.

The fixation treatment is the better method to employ in the more acute cases where pain and night cries are prominent symptoms. The traction method is very useful where the disease is subacute.

A great many cases will be seen where the deformity does not respond completely to either form of treatment. Often the deformity will partially subside, and then, apart entirely from acute muscular spasm, show no tendency to be further corrected. These are the cases in which the faulty attitude has continued

for so long a time that muscular contractions, shortening of ligaments, and adhesions have occurred, and consequently no moderate amount of traction or fixation can affect them. The treatment in these cases is to give

FIG. 276.—Traction Frame for the Application of Extension in the Line of the Deformity in Tuberculous Hip-joint Disease. The frame is shown in use in Fig. 277.

an anæsthetic, and, while an assistant holds the lumbar spine flat upon the table by flexing the sound thigh firmly upon the abdomen, forcibly to

FIG. 277.—Traction Frame Devised for the Purpose of Supporting the Limb and Applying Extension in the Line of the Deformity in Tuberculous Hip-joint Disease. (Original.)

reduce the deformity by a pump-handle leverage action. It is wise to draw the patient to the end of the table in order that the flexion can be over-corrected

and that there may be no elastic tendency to recurrence when the fixation apparatus is applied. Care must be taken in this procedure that the force applied does not produce a fracture of the neck of the femur, which is a possibility if due caution be not observed. At the same time the adduction and external or internal rotation should be corrected, the limb being put up with the foot and knee directed but slightly outward and the thigh in moderate abduction. The maintenance of abduction is of great importance, as this is the attitude which causes apparent lengthening and consequently neutralizes any actual shortening that may have occurred. Also, this is the attitude in which it is most difficult for a pathological dislocation to occur, owing to the conformation of the acetabulum and the neck of the femur and the obliquity of the side of the pelvis. It will be seen from the diagram (C, Fig. 257) that when the thigh is abducted the pelvis is tilted downward on that side, and consequently the angle which the line of force directed up the femur makes with the side of the pelvis is less acute than normal, and as a result the tendency of the head of the bone to slide up the side of the pelvis is diminished. In the case of the adduction deformity the angle in question becomes more acute. Consequently force directed up the femur would have a much greater tendency to displace the head upward by producing the characteristic wandering of the acetabulum or a pathological dislocation. When the deformity has been reduced, either a long spica or a short spica with traction may be applied, the latter being probably the more comfortable of the two.

Following this method of procedure there is seldom much pain if care has been taken to overcorrect the deformity before applying the spica in an attitude which is not overcorrected; usually the temperature rises to 99° or 100° F. for a day or two, but no injurious symptoms in the vast majority of cases have been observed to arise from the procedure. In very rare instances untoward results (tuberculous meningitis) have followed forcible correction of deformity, and therefore it would be wise to reserve this treatment for cases in which there are no symptoms of active disease.

Following the reduction of the deformity the treatment depends upon the severity of the symptoms. If the case is a mild one without much pain, and if the muscular spasm has been largely overcome, the patient may be allowed up in some ambulatory apparatus at once. If, however, the muscular spasm is marked and motion absent, and if there is much tenderness or pain, the patient must be kept in the recumbent attitude, the treatment as outlined above being carried out. In such cases, where the recumbency is likely to be prolonged, it is a good scheme to provide a three-wheeled cart, commonly known in the hospital as a banana cart, upon which the patient may lie instead of being continuously in bed. The cart is about five feet long and eighteen inches wide and is provided with a mattress like that of an ordinary bed. Two large wheels are placed a little behind the middle and a small swivel wheel in front.

By this arrangement the patient can reach the large wheels without rising from the bed, and can move himself about the room at will. This has a great advantage in that it provides exercise that is not injurious and change of scene that relieves the monotony of the treatment.

The question of when to change the recumbent to the ambulatory form of treatment is of the greatest importance. The signs of local acute disease must have markedly subsided, and the patient should have made a substantial gain in general health, before he is allowed to move about. In the very acute cases it is wise to leave him in the recumbent attitude for several months, after the acuteness has begun to subside, in order that the process of repair may be well commenced before any possible strain is applied to the joint. The time in bed may therefore be only a few weeks, or it may be months or even a year, depending on the progress of the case.

Ambulatory Treatment.—In order that ambulatory treatment may be efficient the joint must be provided with nearly as complete rest as when the patient is in bed. In order to accomplish this the joint must be fixed in the proper attitude and the function of weight-bearing eliminated. Some years ago it was claimed by Taylor, Sayre, and other American writers that motion without friction at the hip joint was beneficial. This idea has very few supporters at the present day, the good results obtained by this treatment being attributed to the stilting and partial fixation that their ambulatory apparatus provided. Certain German writers and also some American authorities go to the other extreme and pin their faith entirely on the fixation of the joint, allowing their patients to go about without any provision for the relief of weight-bearing. This has even less to recommend it than the old idea, as the injury caused by the grinding of the diseased articular surfaces together in walking is very considerable. Besides stirring up the disease to renewed activity, this method also is a direct cause of upward displacement of the femur which can by other means be avoided. At the present day the majority of surgeons combine the principles of stilting and fixation, and in looking for an ambulatory apparatus we must choose the one which accomplishes these two objects most efficiently.

The apparatus most commonly used is the long hip brace shown in the photograph (Fig. 278). It consists primarily of an outside bar extending from the mammary line to below the foot. This bar may be solid or spliced, so that it may be extended as the child grows taller. It is quite common also to make the outside bar tubular in form, as suggested by Taylor, and to provide for the extension of the brace by a ratchet and key. To the outside bar are attached three transverse steel bands, for the chest, pelvis, and thigh. At the bottom the outside bar is turned inward at a right angle two and one-half inches to three inches below the foot, and the foot-piece thus formed is shod with sole leather. The transverse bands are well padded and covered with leather or plush. The

pelvic band is provided with four buckles, two close together in front, and two well separated behind. To these are attached perineal bands which, passing under the perineum, support the body weight in walking. These bands are made of strong tape, well padded, and covered with chamois leather. At the foot of the brace are attached three straps, one behind and one on either side. When the brace is applied the posterior strap is fastened into a buckle which is riveted to the heel of the boot, and the side straps are fastened to the buckles on the ends of the adhesive-plaster extensions described above. These latter straps were originally intended to produce traction upon the limb, but the difficulty of keeping the brace accurately adjusted makes this practically impossible. They serve a useful purpose, however, in steadying the limb and thus assisting in its fixation. The heel strap when tight draws the heel down and lifts the toes up, thus providing against the patient touching the foot to the ground and bearing the body weight.

Fig. 278.—The Long Hip Brace used in the Ambulatory Treatment of Tuberculous Hip-joint Disease. (Original.)

The splint being two and one-half inches or three inches longer than the leg, we must raise the healthy side a corresponding distance. This is done by placing two and one-half inches or three inches of cork between the outer and inner soles of the boot. Cork is the best material, as it is both strong and light. A metal patten may be used if an orthopedic shoemaker is not available. The splint is applied over a soft undershirt, the perineal straps and transverse bands are tightened, the traction and heel straps are made taut, and the patient is ready to walk. At first he will find it difficult, but within a few days he ought to be getting about without assistance.

When a patient leaves the hospital, wearing a long splint, a list of instructions is given to the parents in order that efficiency may be maintained in the treatment. The brace must be worn night and day, only being removed by the surgeon or the nurse. Care must be taken to see that the perineal straps do not cause excoriations. It is wise to rub the parts with alcohol daily and to apply some drying powder. Every three or four weeks the adhesive

extension must be changed, care being taken to avoid putting the new plaster over skin which had been covered before. By this precaution sores are prevented.

There are several hip splints, the efficacy of which depends on the same principles as the above, but which differ in some of the mechanical details. One is the Phelps hip splint, which, instead of having perineal straps, has a padded steel ring attached to the outside bar and so adjusted that it fits snugly about the thigh and supports the body weight in the perineum. This device has the advantage that it prevents antero-posterior motion, unlike the ordinary chamois straps, and it also cannot be tampered with by the patient or his parents. It has the disadvantage that it is difficult of adjustment and in the case of small children is liable to be soiled.

It will be observed that the treatment of hip disease by apparatus such as the above is in reality a combination of the old Taylor and Thomas methods of treatment.

The Taylor brace was similar to the above, except that the outer bar did not extend above the pelvic band, the thoracic band being absent. The brace depended for its efficiency upon the fact that it stilted the patient and that it attempted to provide constant traction upon the limb. Unfortunately, it did not provide against motion at the joint, and in consequence the deformity of flexion and adduction frequently developed. The fact also that during its employment there often occurred acute exacerbations which were immediately relieved by fixation of the joint in a spica or a Thomas hip splint, was suggestive that an apparatus which should effectively splint the joint would provide the more efficient treatment. As a consequence, the old Taylor brace is seldom seen nowadays in the treatment of acute disease.

Fig. 279.—The Thomas Splint applied in the Ambulatory Treatment of Hip-joint Disease. (Front view).

The Thomas splint has been described above. When it is used in the ambulatory treatment a sling is attached to the top of the splint and passed over the shoulder to prevent its slipping down (see Figs. 279 and 280). A high boot is placed on the opposite foot, and the patient gets about with the aid of axillary crutches, obviously swinging the foot of the affected side free of the ground. The great

disadvantage of this, of course, is that in many cases the children will not use the crutches, and are found running about in a lop-sided fashion, bearing the full body weight on the diseased limb.

The advantage of the combination of the two ideas is at once evident, as the good points of each—the stilting of the Taylor brace and the fixation of the Thomas splint—are both employed.

The disadvantages of the long splint are not a few, however. The splint in extending up to the mammary line prevents free motion of the spine. As a result the patient is unable to sit down properly and sometimes complains of discomfort on this account. Again, the appliance, to be effective, requires constant supervision to see that the bands—perineal and traction straps—are always correctly adjusted. Finally, even with ordinary care, the splint never perfectly fixes the joint, and flexion and adduction sometimes develop.

Fig. 280.—The Thomas Splint Applied in Ambulatory Treatment of Hip-joint Disease. (Back view.)

In the great majority of cases, however, the brace will be found to be entirely satisfactory, and the good results which have been obtained from its extensive employment in the hospitals and dispensaries of America is a good guarantee of its efficiency.

In order to obviate the objections offered to the use of the long hip splint, Whitman, of New York, has recently advocated a combination of the plaster spica and a small stilting brace. Fig. 281 shows this apparatus applied, but without the traction straps. These straps may be omitted in the less acute cases. A Lorenz spica is applied, care being taken to fit it snugly about the crests of the ilia, and provision being made against adduction by incorporating buckles in the plaster for a perineal strap, as described above. The spica is applied over the ordinary traction plasters. Over the spica is loosely fitted a crutch brace of the type shown in the photograph. It consists of an outside bar terminating below in the ordinary foot-piece, which is provided with the

three straps in exactly the same manner as is the long brace described above; the bar ends opposite the hip joint and is attached to a transverse steel band which extends anteriorly and posteriorly sufficiently far to support buckles for the attachment of a single perineal strap. Usually the part of this transverse band behind the vertical bar is bent upward a little to fit the plaster and to escape the uncovered buttock. Just above the knee is a transverse band which holds the brace against the thigh. The whole brace is loosely applied, so that when the patient places his foot on the foot-piece the body weight will not be transmitted through the thigh to the brace, but will be entirely supported by the perineal band, no weight being transmitted through the plaster spica.

Fig. 281.—Whitman's Short Stilting Brace and Plaster Spica Used in the Ambulatory Treatment of Tuberculous Hip-joint Disease. This may be applied with or without traction, as may be desired. (Original.)

By this scheme we have almost perfect fixation of the joint, combined with efficient stilting. The spine, being unencumbered, is allowed free movement, and the patient is enabled to sit up in a chair without difficulty. The spica prevents the possibility of injury to the joint, whereas such injury may occur where there is neglect in looking after a brace. The device has also the advantage that it is light, the spica weighing little over a pound, and the small brace containing the minimum amount of steel.

This method has been employed in the Hospital for Sick Children, Toronto, and has given complete satisfaction. It has been found that, owing to the efficiency with which it provides rest to the joint, recumbency may be abandoned much earlier than otherwise, and sometimes may be dispensed with altogether. The difficulty, of course, is in the application of the spica, which requires care to make it efficient. In addition to this form of treatment it is suggested that the traction straps should be unbuckled at night or that the entire brace should be removed and a weight attached to create traction during sleep. The weight may be attached to the foot-piece of the brace while the traction straps are still attached to it, and the same result may be thus accomplished.

Treatment During Convalescence.—As the symptoms begin to disappear and convalescence is established, the necessity for the same rigorous treatment

lessens. In the Hospital for Sick Children, Toronto, the first change is to give freedom to the spine and to permit some motion at the hip. If the long splint has been employed, the upper part of it is removed and it is converted into a Taylor hip brace. If the short spica and crutch brace have been used, the spica is dispensed with and the effect of the change carefully watched. If after several months or a year the improvement continues, the complete stilting is replaced by what is known as the caliper brace (Fig. 282). This is simply the Taylor brace from which the foot-piece has been removed and which has been attached to the shoe by a free joint through the heel. By keeping the perineal straps tight, part of the body weight will come on the straps and the rest on the leg. In this way too much work is not thrown on the diseased hip at once.

Fig. 282.—The Caliper Brace Used in the Ambulatory Treatment of Hip-joint Disease.

Another plan which has proved very satisfactory is to dispense first of all with the stilting. Thus, where the Whitman crutch brace and short spica are used, the crutch brace is first changed to a caliper brace and finally removed, the spica being retained for many months longer. In the case also where the long brace has been employed, it is removed and a spica applied. The spica is first extended down to the ankle, but is later cut off to allow free motion at the knee. An advantage in this form of treatment is that the flexion and adduction that so often occur during the later stages of the disease are entirely prevented by the plaster of Paris.

Finally, if it is found that no exacerbation has resulted from the change in treatment after several months' trial, all apparatus is removed. The patient must be kept at this time under closest observation in order that early information of the fact may be gained in the event of a recurrence. If acute symptoms develop, the patient must be immediately brought back to the original form of treatment and the same process gone through as before.

Correction of Persistent Deformity.—We have yet to consider the treatment of those cases which have been cured with deformity and also those cases which are seen first when the disease is not yet cured and in which there is resistant

deformity. In the latter class of cases, where the disease is still active and where there is ankylosis in flexion and adduction, the wisest plan is to devote the entire attention to completing the eradication of disease before interfering with the deformity. No operative procedure should be attempted until all sinuses are firmly healed and the process of repair is well established. When a cure has been obtained, attention may be turned to the deformity, which is usually flexion, adduction, and external or internal rotation (Fig. 283). In those cases in which there is slight motion, and the head of the bone, or part of it, is still in the acetabulum, an attempt should be made to reduce the deformity by forcible manipulation. The patient is anæsthetized and the thigh levered down as described above, the attitude being changed to full extension, slight abduction, and the proper amount of external rotation. A plaster spica is then applied. This should be worn a long time to allow the adhesions, etc., to form in the new attitude and thus prevent recurrence. The patient, of course, is allowed to walk with the use of crutches.

Fig. 283.—Fixed Deformity in Tuberculous Hip-joint Disease. Ankylosis has occurred and the thigh is flexed and adducted, with outward rotation. (Original.)

Instead of the forcible manipulation and the application of a spica, a scheme sometimes used is the employment of an abduction brace (Figs. 284 and 285). This consists of an inside bar ending below in the ordinary foot-piece and straps described in the other ambulatory braces, and above in a perineal crutch which fits into the junction of the thigh and perineum on the side opposite to the diseased hip. This crutch is padded carefully to prevent soreness. The upright bar is made in the form of a tube and is extensible by means of a ratchet and key. When the brace is applied and the traction straps have been tightened by extending the inside bar with the key, the leg is forcibly abducted owing to the slight angle between the leg and the bar of the brace. A high shoe is put on the other foot, and the patient is allowed

to walk. By tightening up the traction each day, very resistant adduction deformity can be sometimes overcome, and, if the brace is worn sufficiently long, it will not recur.

In cases where there is upward displacement of the femur, the head having been absorbed or dislocated, or where there is an ankylosis too strong to be broken down by manipulation, the only treatment of value is subtrochanteric osteotomy. If the deformity is reduced by forcible manipulation it invariably recurs on account of the absence of the outward leverage of the neck of the femur and on account of the contraction of the powerful adductors which are left unbalanced owing to the mechanical obstruction offered to abduction by the proximity of the trochanters and the side of the pelvis.

FIG. 284.—Abduction Brace for the Correction of Deformity in Hip-joint Disease. (Front view.)

In performing subtrochanteric osteotomy an osteotome of the variety known as Vance's may be used. It is about one-half inch wide at the edge and the shaft is very small, so that the opening made by it is of minimum size. The osteotome is passed through an incision in the skin at a point just below the trochanter minor on the outer side of the thigh, with the blade in the long axis of the limb. After it has passed through the periosteum it is turned at a right angle to the bone and the outer table of the shaft cut through by a series of little nicks in a line exactly across the femur. When this is completed the thigh is levered away from the cut in the bone and broken across. The limb is then abducted and extended and rotated inward to any attitude that may be desired. Before deciding the attitude one must refer to the measurements of the legs and ascertain the exact real and the apparent shortening. If there is no real shortening the limb should be put up in very slight abduction. If there is considerable shortening this may be partially overcome by putting the limb up in more marked abduction, thus producing an apparent length-

ening on the crippled side by tilting the pelvis. The flexion should not be completely reduced, as it is very convenient for the patient to have a little flexion when sitting down. Care must be taken to have the foot and knee rotated slightly outward. When the deformity is corrected, a spica is applied from the mammary line to the toes, and the patient is left in this for about six weeks. In the case of adults it is a good scheme after the plaster is firmly set to cut out the front of the spica from the top down to the umbilicus, leaving the posterior portion to extend up to the mammary line. In this way the obstruction to free breathing and the discomfort after eating are removed without interfering with the efficiency of the apparatus. At the end of six weeks the spica is cut off at the knee to allow movement at that joint, and at the end of eight or nine weeks the plaster is removed and a short spica applied, after which the patient is allowed to walk. This is used for a month or so to make sure that union is firm.

Fig. 285.—Abduction Brace Used for the Correction of Deformity in Hip-joint Disease. (Back view.)

Treatment of Abscess in Hip Disease.—During the progress of hip disease, abscess formation is a frequent complication. So long as it remains quiescent as a closed sac it in no way adds to the seriousness of the condition. If, however, it becomes infected by pyogenic organisms the resulting disturbance proves the most troublesome and most fatal complication of the disease. Infection may take place by communication with the skin surface following incision and drainage, or through the open wound which is left by the bursting of the abscess. Infection frequently takes place also without any break in the skin, owing to the abscess cavity approaching too closely to the surface and communicating with the cutaneous glands and follicles.

When the course of a tuberculous abscess is watched it is frequently seen to grow to a certain point and then to cease growing. Gradually the fluid part of the contents is absorbed, the solid part becomes organized, and finally noth-

ing is left but a slight thickening of the tissues. In other instances the abscess continues to grow rapidly and soon comes close to the skin, burrowing along the paths of least resistance. During all this time there has been no disturbance of the patient from the presence of the abscess, there being no rise of temperature and no local signs of acute inflammation. If, however, infection with other organisms occurs, the clinical picture changes and we have high fever, malaise, loss of weight, and the other links of the hectic chain. Copious discharge often takes place from the sinuses communicating with the abscess cavity, and, if the patient lives, this will probably continue for years. As a result of the long-continued suppuration amyloid degeneration of the viscera is frequently added, and, where this advances very far, death invariably results.

The indications for the treatment of an abscess are based upon these considerations of its clinical course and upon what we know of its essential structure, as already described in our consideration of its pathology (page 580). These indications may be summarized as follows:

First. To keep the cavity sterile.

Second. To prevent its enlargement to such a size as to be injurious.

Third. Where it is large, to remove it and prevent its recurrence.

The plan of treatment adopted aims at following these indications. It is divided into expectant and active phases. When it is discovered that an abscess is developing, the patient is immediately returned to recumbency in order that the possibility that the abscess is developing by reason of insufficient rest at the articulation, may be eliminated. The size of the collection of fluid is carefully noted, and from time to time it is examined to detect any variation in size. If it is found that the abscess does not enlarge much and finally ceases to grow, it is left severely alone in the hope that nature will effect its own cure. If, however, it continues to enlarge, steps are taken at once to head it off in order that, in the first place, there may be a minimum involvement of the soft structures, and, secondly, in order that infection from near approach to the skin may be prevented.

Never allow a tuberculous abscess to get near the skin, is a rule to be remembered, for not only is there danger of mixed infection, but the fact that the tissue between the skin and the abscess is thin makes firm union impossible after incision, and as a result breaking down frequently takes place even after primary union.

A common practice is to aspirate the cavity through a large needle, but this method has nothing in it to commend it, as more certain results are obtained by incision without drainage, carried out in a special manner to be immediately described.

Moreover, the contents of these cold abscesses are often too thick to be withdrawn by means of a needle. In many cases, too, the emptying of the cavity seems to have no effect on the course of the abscess; consequently some-

thing more radical has to be done with a view of removing the disease in the abscess wall.

The usual procedure in such cases is freely to incise the abscess through the thickest part of the tissue intervening between the sac and the skin and opposite the least dependent point in the abscess, and thoroughly to evacuate its contents. If the abscess has approached so near the surface that the tissues immediately over it are very thin, then it is wise to make one's incision sufficiently far from the abscess to cut through a good thickness of healthy tissue before the cavity is reached. This will more efficiently insure primary union after suture than would be the case if the thinner layer of tissue were incised and sutured. The walls of the sac are then dissected out or curetted with a flushing curette. The cavity is finally thoroughly wiped out with iodoform gauze on a clamp, for the purpose of removing as much débris as possible. The wound is then sewn up tight, a deep layer of absorbable sutures being put in to make a thick wall, and a sterile dry dressing is applied.

The results of this plan have been very satisfactory. My colleague, Dr. C. L. Starr, of Toronto, has reported 55 cases treated in this way at the hospital. In seven the wound broke down after being sewn up, and in 48 cases, as far as could be traced, it remained perfectly closed for periods varying from four months to six years. Only 5 of the series required a second evacuation of contents, and 1 a third. In one case the wound healed by primary union, and at the end of two weeks broke down and discharged a quantity of tuberculous material. The cavity of the abscess was then again thoroughly curetted, and the edges of the wound were excised and sewn up tightly. This time firm healing took place, and there has been so far no recurrence.

The greatest care must be taken in the aseptic technique of this operation, as the unhealthy tissues are more liable to infection than normal structures.

The writer has employed this method of treating tuberculous abscesses for the past ten years, and from his experience he would urge that it is absolutely unjustifiable to drain a tuberculous abscess unless mixed infection has occurred. One patient who developed a very large abscess in hip disease was treated in this way six years ago. The incision healed by first intention and there has been no recurrence. Another patient, two years after the onset of hip disease, developed an abscess which approached the surface on the outer aspect of the thigh. It was opened and treated and it healed by first intention. Ten months afterward another abscess developed, on the inner aspect of the thigh; this was treated in a similar fashion and it also healed by first intention. It is now three years since the last operation, and there has been no recurrence, and the child is now going about without a splint.

Various modifications of this treatment have been employed. It was suggested by Mikulicz that abscesses be treated by aspiration and the injection of a ten-per-cent emulsion of iodoform in glycerin; or, if incision and evacua-

tion are employed, to leave an ounce or so of this emulsion in the abscess cavity. This plan was given a thorough trial in various hospitals on this continent, and the consensus of opinion is that it is not of any particular value in the treatment of cold abscess and that sometimes it seems to prevent the collapse of the cavity, after evacuation, by the dehydrating action of the glycerin on the tissue.

It was formerly the custom to mop the cavity thoroughly with pure carbolic acid or some other caustic before closing the skin. This has now been abandoned, as it has no particular advantage.

The pernicious custom of incising tuberculous abscesses and employing iodoform gauze or tubes for drainage purposes cannot be too strongly condemned, as it always ends in infection of the cavity, and long-continued suppuration is the invariable result.

Treatment of Suppurative Hip Disease.—In those cases which have been infected with pus organisms as a result of the communication of the abscess cavity with the skin, the whole secret of successful treatment lies in the provision of perfect drainage. If the pus is unable to find its way to the surface easily it will rapidly strip up the tissues and soon create a honeycomb of sinuses about the joint. If, on the other hand, efficient drainage is provided, there is every probability that the infection will be limited to the area already involved, and in consequence a minimum amount of damage will occur.

When the disease is acute these sinuses should be left alone, the surgeon only interfering to keep the passage to the bottom of the cavity free. The dressing should be done once or twice daily, as the amount of the discharge demands. Drainage may be provided for by gauze or by tubes, the latter being usually the more efficient. When the sinus is long and tortuous a good plan is to use a soft-rubber catheter. On account of its rounded nose this can be slipped in and out without injury to the tissue or discomfort to the patient. When the discharge is profuse it is customary to irrigate the sinus daily. A good method of doing this is to attach the irrigator to the catheter mentioned, and, when the eye of the catheter is at the bottom of the cavity, to turn on the fluid. Normal saline solution is practically always used by the author in the irrigation of sinuses, the theory being that it has all the advantages of the other fluids without their injurious effect on the tissues. It is simply used to wash out the pus.

The treatment as already described for the acute non-suppurative cases must be carefully carried out also in those cases where suppuration is present. In order that the hip may be disturbed as little as possible during the dressings these children may with advantage be provided with the adjustable bed splint described above (Fig. 273). At the region of the hip the outside bar is bent into a loop so that the dressings can be applied and the bandage adjusted without interfering with the fixation of the joint or the traction on the limb.

The plaster spica cannot be used in the majority of cases on account of the discharge of pus.

After the acute stage has passed off, unless it seems likely that extensive necrosis of bone has taken place, it is better to leave the sinuses alone. If there is much dead bone in the cavity this should be removed by curettage or excision of the joint. Frequently the discharge from the sinuses gradually diminishes until nothing is left but a tuberculous fistula. This will remain open for an indefinite time, and the best method of dealing with it is thoroughly to remove the diseased granulations.

Excision of the Hip.—The indications for excision of the hip in tuberculous disease are limited. It should be done where it is otherwise impossible properly to drain the joint, and is specially indicated when amyloid disease becomes evident, and, lastly, when there is reason to believe that there is extensive necrosis of the head or the acetabulum, or both.

A suitable operation for these cases, where perfect drainage is required afterward, is that in which a posterior incision is employed. The patient is rolled over on the sound side, the thigh is semi-flexed and rotated a little inward, and a four-and-one-half inch incision made extending from about two and one-half inches above the tip of the trochanter to a point two inches below. The incision is deepened to the capsule, and the surface of the trochanter is laid bare by separating the glutei muscles. The capsule is now opened and all the muscles on the front of the trochanter and on the back are removed, the leg being rotated to assist this operation. The saw is now applied and the head, neck, and trochanter may thus be removed, if necessary. By this procedure an excellent view of the joint can be obtained and all diseased capsule and bone may readily be excised. The wound is then packed with iodoform gauze to control hemorrhage.

The secret of the success of this operation in saving life is that it provides excellent drainage. In order that this may not be lessened, sufficient traction must be applied to the limb to prevent the extremity of the femur from being displaced upward and thus closing the wound. During the period following the operation, adequate fixation must be provided, with the limb in a correct attitude. This is best gained by the use of the bed splint described above, or by the use of a Thomas splint with traction.

The results following excision are not very satisfactory. At the Hospital for Ruptured and Crippled in New York, Townsend reports 99 cases, with 51.5 per cent of deaths, and Bradford and Lovett report 44 per cent of deaths in 50 cases at the Boston Children's Hospital. These statistics also include cases that were not septic previous to the operation, so that the percentage in this class of cases for which the operation is advocated would be considerably higher. On the other hand, if excision is not performed in these cases, practically all die, so that the operation is frequently valuable as a life-saving measure.

It was formerly a common practice to do an excision earlier in the course of the disease for the purpose of extirpating all tuberculous tissue, and thus it was hoped to cut off several years of treatment. The objections to this plan are so strong that it has been largely given up. In the first place, the mortality is extremely high, ten per cent, according to Wartmann, dying, very soon after the operation, of acute miliary tuberculosis, and many others dying of shock or sepsis. In the second place, one is not always successful in eradicating all the disease, and consequently, after the operation, the conditions are not materially bettered. And, finally, the result, at best, is not a good one, as the joint has been destroyed and its function as a stable support of the body is abolished. Ankylosis in correct attitude is a far better result to aim at than the unstable joint that is left by an excision.

Local Operative Measures.—We have already stated that the removal of limited foci of disease cannot be carried out in the hip as is occasionally possible in connection with tuberculous arthritis in other parts of the body. The exception here is perhaps in certain cases of tuberculous deposit in the outer part of the femoral neck. Symptoms of localized pain in the region of the trochanter major or the evidence of focal disease as demonstrated by an x-ray photograph may lead to the diagnosis of such a lesion, and its eradication may be possible by operative means. We cannot advise this as routine treatment, but in individual cases where the progress, the extent, and the duration of the disease are taken into consideration along with the constitutional condition of the patient, it may be thought wise to cut down upon the trochanter major, and by tunnelling through this into the femoral neck the lesion may be reached. The writer has succeeded thus in reaching a lesion in the outer part of the femoral neck without opening the hip joint, and by this means getting rid of the disease by operation, thus preventing the possibility of invasion of the joint structures. Such an operation, if successfully carried out, will of course secure a perfect functional result so far as the hip joint is concerned.

Amputation.—Amputation may be considered as a last resort after excision has failed to relieve the conditions in suppurative cases. It may be impossible to remove the disease completely because of advanced acetabular involvement, but in extensive disease of the pelvis amputation may be useful in providing conditions under which more efficient drainage is possible. Howse has suggested the removal of the limb in instalments; amputation being first performed at the knee, and subsequently—after the patient has recovered from the operation—at the hip. It is claimed that the removal of the weight of the leg, when the patient is suffering greatly from pain and distress, has a markedly favorable effect upon the progress of the case, so that subsequent amputation at the hip is attended with less shock and is more likely to be successful. It happens very rarely that amputation is necessary in hip

disease, and, when it is so, the conditions must necessarily be very unfavorable for the attainment of a successful issue after such a formidable procedure; hence it is that the mortality after amputation at the hip for tuberculous disease is very high, and it is rare that ultimate and complete recovery takes place after operation. It has been noted that tuberculous meningitis has supervened in certain cases after amputation for hip disease. If all these facts be taken into consideration it must appear evident that amputation can be considered only as a forlorn hope.

The Bier treatment, which consists in producing stasis hyperæmia in the diseased joint by bandaging the limb above the articulation, is of course inapplicable in the case of the hip joint because of its anatomical situation. The principles involved in the Bier treatment are discussed at length at page 590, and it is quite possible, if hyperæmia thus artificially induced is proved to be of specific value in the treatment of tuberculous disease of the joints, that some means will be found to apply the treatment to the hip. Thus it would appear possible to induce active hyperæmia by means of the hot-air apparatus, as this has been shown to have much the same effect as passive hyperæmia produced by bandaging.

Lastly, we may note the value of the treatment of hip-joint disease by means of Wright's tuberculin opsonic method. A full description of the method of using this therapeutic agent is described at page 592, and its value in the treatment of tuberculous arthritis is there fully discussed. It has been employed with apparent benefit in these cases, and it is being employed in the Hospital for Sick Children at present, but it is too early to state what the final results attained may be. Sufficient work has been done in connection with this form of treatment to convince one that it is an important and useful adjunct to the local treatment which we have already described

Double Hip-joint Disease.—Occasionally there exist bilateral manifestations of tuberculous disease in the hip joints. When this unfortunate complication occurs the difficulties of treatment are increased, because obviously many of the methods of dealing with the disease which we have described are inapplicable here. This is chiefly the case as regards the ambulatory treatment, and, as a fact, when double hip-joint disease exists we are forced to treat the patient in the recumbent position throughout the greater part of the course of the disease.

The same principles must guide us in our methods of treatment. Traction and splinting must be employed in the acute stages of the disease. If plaster of Paris is used it must be a double spica, or a double Thomas splint may with advantage be employed. When convalescence sets in and all acute symptoms of disease have disappeared, a double long hip brace may be procured and the patient permitted to go about on crutches, but locomotion in this way is exceedingly difficult as compared with the conditions which exist in disease re-

stricted to one side, as the patient cannot well move about without the use of one sound free limb.

If the final result should unfortunately be that of ankylosis of both hips the patient will walk with difficulty and with a very awkward gait. In such cases it has been suggested that an excision of one hip should be performed with the hope of securing a certain amount of movement.

Involvement of Other Joints in Hip Disease.—Difficulties may arise by reason of such complications. Thus, Fig. 286 is a photograph of a patient with knee-joint affection on one side and hip disease on the other. Here, again, the principles of treatment already laid down are to be observed. As in double hip trouble, so here the treatment must be carried out for a much longer period in the recumbent attitude, but in convalescence progression is possible with a combination of a Thomas knee splint on one side and a traction long splint for the diseased hip.

Fig. 286.—Tuberculosis of the Left Hip and Right Knee in the Same Patient. The child was eight years of age. The hip disease developed three years previously and became quiescent, with one inch shortening of the limb, when the knee disease manifested itself. (Original.)

More commonly, Pott's disease of the spine is combined with hip disease. It has been suggested that infection spreads from the spine to the hip by means of a psoas abscess which has reached the hip joint by way of the ilio-pectineal bursa (see page 627). Here, again, the recumbent attitude is necessary for a longer period than in uncomplicated hip disease. When convalescent, however, the patient may get about on crutches with the necessary splints and braces.

Tuberculous Disease of the Knee Joint.—As in the hip so in the knee, the most common affection of the joint is tuberculous disease. This is markedly the case in childhood, as is evidenced by the following statistics from the Hospital for Sick Children, Toronto. Of 115 cases of disease of this articulation admitted into that institution the following indicates the conditions found:

Acute and chronic synovitis	19
Acute suppurative arthritis	7
Arthritis deformans	1
Syphilitic arthritis	3
Hæmophilia	1
Loose cartilages	1
Ankylosis from conditions not determined	7
Tuberculous arthritis	76
Total	115

In these children fourteen years of age and under, therefore, the tuberculous affections amounted to 66.1 per cent of all cases of affections of the knee joint admitted to hospital. In the same institution it was found that, of 315 cases of tuberculous arthritis admitted to the wards, there were 52 (representing 13.2 per cent) of disease in the knee joint. From these statistics it would appear that tuberculous disease of the knee joint is only about one-fourth as common as similar affections of the hip, which, as has already been stated, amounted to 53.6 per cent.

Tuberculous disease of the knee is much more frequent in the adult than is a similar condition of the hip. The fact that this affection is comparatively common in the adult is shown by the statistics of Koenig of 704 cases, as follows:

1– 5 years	143
6–10 "	149
11–15 "	101
16–20 "	89
21–25 "	54
26–30 "	39
31–40 "	53
41–50 "	33
51–60 "	25
61–70 "	18
	704

Here, however, as in the hip, the first decade of life gives us the largest number of cases. Thus, in the above statistics, 41.4 per cent of the cases occurred at that period of life.

Anatomical Considerations.—It is not necessary here to describe in detail the anatomy of the knee joint, but reference may be made to some special features of its structure which have a particular bearing upon the course of tuberculous disease.

The knee joint is the most complicated articulation in the human body. It is also the most extensive joint, and this is the case whether we take into account merely the extent of the articular cartilage or the size of the synovial sac. At the time of birth, the articular extremities of the femur and tibia, which here form the joint, are almost wholly cartilaginous, as is also the patella. The centre of ossification for the lower epiphysis of the femur usually appears shortly before birth, and so too may the centre for the upper epiphysis of the

tibia, but the latter is somewhat later in appearing than the former. Ossification does not appear in the patella until the third year of life. Even up to the end of the third year a considerable thickness of cartilage still surrounds the ossific centres in the femoral and tibial epiphyses. The femoral epiphysis includes the condyles and the articular surface of the bone anteriorly. The tibial epiphysis includes the tubercle of the tibia. The disc of cartilage which separates the femoral shaft from its epiphysis persists until the twenty-first year. The plane of the cartilaginous disc is transverse to that of the axis of the femur, and is situated immediately below the adductor tubercle, which may be taken as a surgical landmark in locating it. (Consult also the article on "The Epiphyses and their Radiographic Interpretation," page 578, Vol. I).

Similarly, the epiphyseal cartilage of the tibia, which persists until the twenty-first year of life, lies in a plane at right angles to the axis of the tibial shaft; it

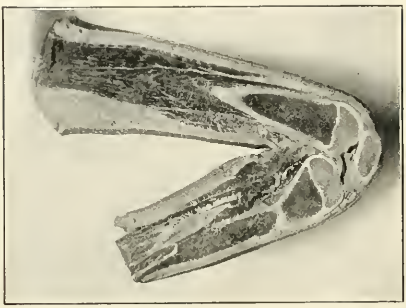

Fig. 287.—Section through the Knee Joint of a Child Nine Years of Age, Showing the Epiphyseal Cartilages. (Original.)

lies for the greater part immediately above the tubercle of the tibia, but dips downward anteriorly to include that tubercle. In Fig. 287 these two epiphyses are seen in a child nine years of age. The growth in length of the limb depends largely upon the persistence of these cartilaginous discs, and if, because of disease or of injury, these cartilages are destroyed, there is great interference with the growth of the bones, and marked disparity will result in the length of the two limbs, the degree of shortening depending, of course, upon the age of the child at the time when the cartilage is destroyed.

The cancellous bone, of which the epiphyses are composed, has a thick covering of articular cartilage both in the child and in the adult. In Fig. 288 the structure of the adult joint is seen in sagittal section. The articulating surfaces are incongruent, since the concavities of the condyles of the tibia are less in depth than would be necessary to receive the convexities of the condyles of the femur. In addition to this the semilunar cartilages (menisci), which are developed on

the articular extremity of the tibia, cover the greater portion of the articular cartilage of the tibia and cut it off largely from direct articulation with the femur. (See Fig. 288.)

Within the articular cavity the two crucial ligaments arise from the intercondyloid fossa of the femur and pass to the non-articular surface on the upper aspect of the head of the tibia. These ligaments are derived from the capsular

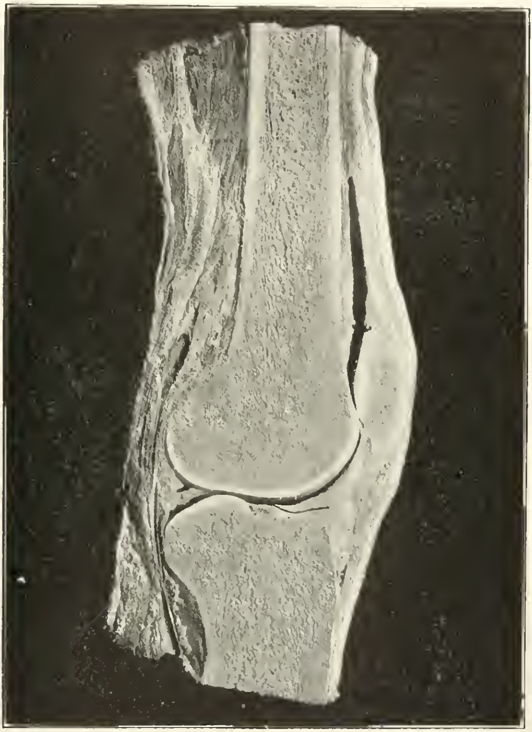

Fig. 288.—Section through the Knee Joint of an Adult, Showing the Extent and Thickness of the Articular Cartilage and the Synovial Cavity Extending upward under the Quadriceps Extensor Cruris Muscle. (Original.)

ligament of the joint, a portion of the posterior part of that ligament being isolated at an early stage of development by the backward development of the condyles of the femur. The anterior surfaces of these ligaments are covered by synovial membrane. They are strong and well developed and materially strengthen the joint by the firm manner in which they attach the femur to the tibia.

The capsule of the joint is re-enforced by special ligaments. The close relationship of the popliteal artery to the posterior ligament is shown in Fig. 288; this must be borne in mind in operations upon the posterior aspect of the joint. The structures bounding the joint anteriorly consist of the extensor apparatus of the articulation, made up of the quadriceps extensor cruris and its tendon, in the substance of which the patella is developed as a sesamoid bone. The tendon of the muscle passes, as the "patellar ligament," to be attached to the tubercle of the tibia. This patellar ligament is quite shut off from the knee joint by a mass of fatty tissue which develops between it and the capsule; further, a bursa, the "deep infrapatellar bursa," exists immediately beneath the ligament; it does not communicate with the knee joint.

The synovial cavity of the knee joint is very extensive. (See Figs. 287 and 288 on pp. 686 and 687.) It lines the capsule of the joint. The fatty tissue behind the patellar ligament is covered by synovial membrane and projects into the joint on either side of the patella as the alar folds or "alar ligaments." There is also a "patellar synovial fold," which arises from the anterior aspect of the capsule and projects backward to be inserted into the intercondylar fossa; this fold is made up of fat covered by synovial membrane. The largest diverticulum of the synovial membrane is the suprapatellar bursa, which extends upward beneath the quadriceps extensor muscle on the anterior aspect of the femur for about a hand's breadth above the patella. It always communicates with the knee joint. Into this pouch of synovial membrane the subcrureus muscle is inserted, and it is separated from the anterior aspect of the femur by a layer of fat (see Fig. 288).

The extent of the synovial cavity in relation to the articular extremities of the bone, and chiefly in relation to the epiphyses, must be mentioned. It will be observed that the synovial membrane does not extend downward below a plane corresponding with the upper surface of the tibial head. Thus it is possible for a tuberculous lesion in the upper epiphysis of the tibia to reach the surface without rupturing into the knee joint, or a tuberculous lesion may be removed by operation in this locality without opening the joint. On the other hand, the synovial cavity extends much farther over the femoral epiphysis. In front, it passes upward as far as the suprapatellar bursa extends, as this bursa is in direct anatomical continuity with the cavity of the joint. Posteriorly, the synovial cavity stops with the articular surface of the condyle. Laterally, however, the synovial cavity is practically confined to a plane corresponding with the upper surface of the head of the tibia, and thus in this region a tuberculous disease of the femoral epiphysis may make its way to the surface without rupturing into the joint cavity, or one may reach a focus in the lower epiphysis of the femur from an incision made on the lateral aspect of the joint without opening the joint cavity.

There are certain bursæ about the knee joint, the existence of which must

be borne in mind when examining for disease. Posteriorly, we have one under the popliteus tendon, another under the semimembranosus tendon, and a third under the inner head of the gastrocnemius muscle. The last two may communicate with the joint cavity. Then there are the subcutaneous prepatellar bursa and a bursa which exists between the fascia and the tendon of the quadriceps extensor muscle; also a subcutaneous infrapatellar bursa between the skin and the patellar tendon. None of these last-named bursæ communicates with the joint, but the existence of disease in any one of them may sometimes be confused with disease in the knee joint.

Etiology.—We have already discussed the etiology of tuberculous arthritis (page 564), and nothing further need be added regarding the causation of disease in the knee joint.

Pathology.—The morbid anatomy of tuberculous invasion of bone and synovial membrane has already been fully described; there are, however, certain peculiarities in the manifestation of tubercle in the knee in consequence of the extent of the articulation, and particularly of the synovial membrane. The synovial membrane on the anterior aspect of the joint is accessible for palpation, and its condition can be determined by examination in a manner which is impossible in such a joint as the hip, for example, where, because of the depth of the articulation and the thickness of the soft parts covering it, such an examination is impossible. The feature here observable is the great amount of thickening of the synovial membrane which is possible in the diseased joint. The extension of the membrane upward under the quadriceps extensor muscle may, in the diseased joint, be found as a thick pulpy pad of tissue which, when cut into, has a grayish, succulent appearance. The histological changes which are manifest in such a condition of the synovial membrane have been described.

While this condition is so familiar in what is termed "white swelling of the knee," one must remember that at an early stage of the disease this characteristic thickening may not be present; there may be marked congestion of the membrane with effusion, rich in fibrin, into the joint cavity. The fibrin is deposited on the surface of the synovial membrane, and in this tuberculosis develops and subsequently invades the subjacent tissue, and eventually a thickened mass of tuberculous tissues replaces the normal synovial membrane. The synovial villi of the joint also become involved and occasionally form exuberant masses of polypoid or filamentous growths projecting free in the cavity. Pulpy masses of tuberculous granulation tissue also push their way insidiously over the surface of the articular cartilage, which in turn becomes invaded by disease. It is seldom one finds any fluid in the joint once the disease has progressed sufficiently to cause marked thickening of the synovial membrane.

The changes which occur in the bone are those characteristic of the invasion of cancellous osseous tissue by tuberculosis, as already described. Here again the

size of the epiphyses at the knee provides an extensive mass of cancellous bone which may be invaded extensively without a communication being necessarily established with the joint cavity; the disease may in fact reach the surface without opening up the joint. A sequestrum may form in the epiphysis. Such a case is illustrated in Plate XXV, Fig. 1, where a sequestrum is seen in the inner portion of the tibial epiphysis in a child ten years of age. On the other hand, the disease may spread to the cartilage and may eventually cause its destruction

Fig. 289.—Advanced Tuberculous Disease of the Knee, Showing Disintegration of the Joint with some Displacement Backward of the Tibia. The patient was thirty-two years of age. (Original.)

more or less completely; the semilunar fibro-cartilages may similarly become involved or destroyed, while the ligaments about the joint, in extensive disease, may become softened and infiltrated. Thus the disease may go on to complete disintegration of the joint, as shown in Fig. 289, where tuberculous disease in a young adult had produced extensive destruction of the articulation. Invasion and thickening of the articular extremity of the bone are accompanied to a greater or less extent by atrophy of the shaft. Fig. 290 is an x-ray picture

of the conditions which obtained in a lad eight years of age, in which the bones of the thigh and of the leg are markedly atrophied.

The disease may begin primarily in bone or in synovial membrane. It is not always easy or possible to determine the starting-point, but at times one can do this with certainty. Of the 691 cases observed by Koenig there were 632 in which he was able to determine the starting-point of the disease, and of these

281 originated in bone, *i.e.*	44.5 per cent
351 in synovial membrane, *i.e.*	55.5 " "

The other 59 cases were undetermined.

From these statistics one would conclude that, in the knee, primary tuberculous disease in synovial membrane is more often met with than primary dis-

Fig. 290.—Skiagraph of Tuberculous Disease of the Knee of Long Standing, showing ankylosis in a faulty attitude of extreme flexion, with marked atrophy of the shafts of the bones and enlargement of the articular extremities. The patient was a lad eight years of age. (Original.)

ease in the bone, but there is considerable variation in this respect, dependent apparently in some instances on the age of the patient. Thus, pure synovial disease is more common in children and young adults, while in patients over twenty years of age the bone is the more usual seat of disease; and, as age advances, the tendency to the production of sequestra is more pronounced, while in younger subjects caseous deposits are more common.

The position of the osseous deposit in the 281 cases reported by Koenig was as follows:

In the patella, 33 cases, *i.e.*	11.7 per cent
Femur, 93 cases, *i.e.*	33.1 " "
Tibia, 107 cases, *i.e.*	38.1 " "
Several bones, 48 cases, *i.e.*	17.1 " "

It would thus appear that the tibia is the most frequent site of the primary deposit; next in order comes the femur, while primary disease in the patella is comparatively rare.

Abscess formation is not an infrequent complication. It is not uncommon to find the abscess develop as an extra-articular formation when, as is not infrequently the case, the abscess forms in connection with a primary deposit in the bone which comes to the surface on the lateral aspect of the joint. Fig. 294 illustrates such a case where an abscess had developed from a deposit in the femur without any implication of the joint cavity. Occasionally the abscess may be very extensive, sometimes burrowing beneath the quadriceps extensor anteriorly, or posteriorly among the muscles of the calf. The frequency of suppuration in 689 of Koenig's cases was as follows:

With suppuration	348 cases
Without suppuration	341 "

In Gibney's analysis of 300 cases 140 developed abscesses and 160 never had abscesses. It would thus appear that the cases are about equally divided. Here as elsewhere the serious nature of abscess as a complication depends mainly upon whether the abscess remains as a purely tuberculous process, or whether mixed infection supervenes; in the latter case the prognosis is much more grave. The point has already been fully discussed (page 645).

Symptomatology.—The symptoms will necessarily vary according to the stage in the progress of the disease at which an examination is made; or, again, these symptoms may differ in primary synovial disease from those present in primary osseous disease. We find the same group of symptoms in disease of the knee that have been already described in hip-joint disease. In the case of the knee, however, the joint is much more accessible for examination than is the hip, and it is possible here to differentiate between lesions of synovial membrane and those of bone in a manner not possible in the hip. In adults the disease not infrequently begins with symptoms of chronic synovitis with effusion into the joint. This condition may persist for months before definite symptoms suggestive of tuberculous disease manifest themselves.

In a typical case of white swelling of the knee we have a clinical picture presented which is very characteristic. In cases in which the synovial membrane is involved—and in most instances, where at all events the disease has not been checked at an early stage in its development, this structure is affected—

knee will present a fusiform shape which is in marked contrast with the normal contour of the parts above the joint. The bony prominences, which are visible upon the sound side, have been effaced; the depressions on the lateral aspects of the patella are obliterated; and the circumferential measurements are found to be increased. These conditions are seen in Figs. 291 and 292, which represent tuberculous disease in the knee in a child three years of age.

The faulty attitude assumed at the knee in tuberculous disease consists of flexion, as is the case in other joints similarly affected. The amount of flexion may not be great, perhaps ten degrees, but it is found impossible completely to

FIG. 291.—Tuberculous Disease of the Knee Joint in a Child Three Years of Age, Showing the Characteristic Fusiform Enlargement of the Knee and the Attitude of Flexion. (Original.)

extend the joint. It is therefore obvious that there is a limitation of movement, and this is not only true of extension, but also of flexion, for we find that complete flexion, which should permit the heel to come back against the buttock, is impossible. Any attempt to bring the joint into a position of complete flexion or complete extension is resisted by muscular contraction. At later stages of the disease, when the ligaments become infiltrated and lax, a varying degree of actual deformity is produced at the knee. The flexion persists while the head of the tibia is drawn backward by the hamstring muscles and rotated outward. This deformity is very characteristic, and is quite constantly present in progressive disease unless measures are taken to prevent its occurrence.

Fig. 293 illustrates the deformity which was present in an adult thirty-two years of age, the disease having existed for six years. In the case figured, the deformity could, of course, not be overlooked, as it is very marked, but one must examine carefully for minor degrees, as the condition when slight is very apt to be overlooked. In the cases of advanced deformity of this nature there may be complete dislocation backward of the head of the tibia, while the flexion may be extreme. Further, the joint may be eventually fixed in the deformed position by fibrous or bony ankylosis. Fig. 290 is a skiagraph from

Fig. 292.—Tuberculous Disease of the Knee Joint in a Child Three Years of Age, Showing the Characteristic Fusiform Enlargement of the Joint. (Original.)

the knee joint of a boy aged eight in whom the joint had become fixed in the attitude described.

Atrophy of the limb is a prominent feature early developed in tuberculous disease of the knee. The skiagraph above referred to (Fig. 290) shows marked atrophy of bone in a long-standing case, but the most notable manifestation of atrophy is in the muscles. Circumferential measurements will show this to be the case when we compare the measurements of the calf and thigh on the diseased side with the corresponding ones on the sound side. The atrophy may be observed by mere inspection, but one is apt to form a wrong estimate of the

degree of atrophy on the one hand and the extent of swelling about the knee on the other, because the wasting of the muscles of the thigh and calf throws the swollen joint out with still greater prominence, leading perhaps to an erroneous estimate of the actual degree of swelling present (for illustration, see Fig. 291), and, again, the degree of atrophy may be erroneously estimated because of the contrast existing between the enlarged joint and the size of the thigh and calf. When one palpates the muscles of the thigh or calf, they feel flabby as compared with the muscles of the sound limb. The nutrition of the skin is also impaired.

The length of the limb in tuberculous disease of the knee may be affected in the production of either shortening or lengthening. It would appear that lengthening is by far the more common condition in the early stages; but, as

Fig. 293.—Advanced Tuberculous Disease of the Knee Joint in a Patient Aged Thirty-two. There is marked subluxation of the head of the tibia, with rotation of the leg outward. (Original.)

time goes on, in consequence of the malnutrition of the limb and retardation of growth as compared with the sound side, shortening results, or it may be produced by actual destruction of the joint structure. Lengthening of the limb is undoubtedly due to increased activity at the epiphyseal cartilage, brought about by the irritation caused by the disease. Increase in length of the diseased limb was first observed many years ago, and Dr. Sydney Jones, in presenting such a case before the Pathological Society of London in 1875, makes the following interesting observation: "In some few excisions of the knee seen some time after operation the author has been struck by the fact that such growth of the limb had occurred as to make the amount of shortening much less than was noted immediately after the operation."

The pain and disability from which the patient suffers vary in different cases. There is usually well-marked though slight increase in heat in the diseased joint. Even where no actual displacement of the bones has occurred, there is still some lameness, the patient moving about with slight flexion of the joint and complaining of feeling tired after slight exertion. There may be little or no pain, but after a time the joint becomes stiff and the limitation of movement becomes more marked.

Where the disease is primarily synovial and is confined to that membrane, one is able to define readily the pad of thickened tissue which represents the suprapatellar pouch. The upper limitations of this pouch are readily felt and can be rolled under the examining fingers. The thickened membrane has a soft, elastic feel, but does not fluctuate. There is no enlargement of the bone; there is usually very little pain; but there is necessarily some restriction of movement. One feature of this synovial type of the disease is the early and rapid occurrence of muscle atrophy. The disease in the synovial membrane may be distinctly localized, and occasionally pedunculated masses of tuberculous tissue may project themselves into the suprapatellar pouch from the synovial membrane; they appear to arise most frequently in the region of the semilunar cartilages. Such structures have been mistaken for "loose bodies," but they are usually of larger size and are attended by some thickening of the synovial membrane in their immediate neighborhood.

Where the osseous tissue is primarily affected we find a varying degree of thickening of the bones. In the early stages and where the disease is limited to a small focus there may be a localized area of tenderness found on pressure, and such foci should be very carefully sought for in cases in which early disease is suspected. These foci are most commonly found in the femoral condyles, more frequently the internal condyle. Occasionally it is in the head of the tibia, and still less often in the patella. The x-ray will often help to establish a diagnosis otherwise doubtful.

The most acute symptoms of knee-joint disease are found in those cases in which the tuberculous process begins in bone, and, after persisting for some time, suddenly breaks into and invades the joint cavity. Great pain is experienced in such cases, and the joint becomes flexed and is held rigidly by muscular spasm. These cases, as a rule, go on to rapid destruction of the joint structures, with infiltration and thickening of both bone and synovial membrane, while muscle atrophy is pronounced. The characteristic deformity of dislocation backward and rotation outward is brought about as the ligaments become softened and relaxed.

Abscess formation may occur, and this may be either extra-articular or intra-articular. The former most frequently arises from a deposit in the bone which has come to the surface without invading the joint cavity. Such a case is shown in Fig. 294, that of a patient six years of age who had a lesion of the

internal femoral condyle, and in connection therewith an abscess which came toward the surface. The abscess was treated in the usual manner without drainage, and it healed by first intention, the child recovering eventually with perfect functional result so far as the joint was concerned. Fig. 250 represents a microscopic section of a portion of the wall of the abscess in this case. Then, again, an abscess may make its way into the joint cavity, either from synovial membrane or from bone. In such cases the symptoms of acute involvement of the joint come in evidence, there is much pain, and often night cries are

Fig. 294.—Tuberculous Disease of the Left Knee Joint in a Child Aged Six Years. The swelling on the inner side of the knee is an abscess which healed by first intention after evacuation in the manner described in the text. Fig. 250 represents a section of part of the abscess wall. (Original.)

troublesome complications. These cases again usually go on to extensive joint destruction.

Cases may go on to recovery with marked deformity. These are cases which have not been subjected to efficient treatment. It is not uncommon in hospital practice to have patients admitted in whom the disease has become quiescent, but with the joint ankylosed in a position of flexion with dislocation of the tibia backward and rotation outward. In some of these cases the flexion may be so extreme that the limb is useless as a means for progression.

Knock-knee may also occur as a late deformity in patients who have at-

tempted to go about and use the limb when fixed in the deformed attitude of rotation outward and backward dislocation. Then, again, destruction of the internal condyle may in rare instances produce genu varum.

The degree of constitutional disturbance in tuberculous disease of the knee varies greatly. Most frequently the disease is purely local and there are no constitutional effects discernible. In acute manifestations, however, the temperature becomes elevated and the pulse quickened, with general malnutrition. If mixed infection occurs, then symptoms of septic absorption speedily appear, and from long-continued suppuration the usual train of symptoms supervenes; visceral disease, with amyloid changes in the kidneys, liver, etc., may eventually prove fatal.

Diagnosis.—It is not a difficult matter, as a rule, to diagnose a tuberculous knee joint. The symptoms, which have already been detailed, are sufficiently characteristic. Careful inspection and accurate measurements must be made, while by manipulation localized or diffuse swelling may be determined, and the existence, or otherwise, of points tender on pressure may be noted. It is important to observe, not only a faulty attitude, but any limitation of movement which may exist.

The *x*-ray is a very important aid to diagnosis. This is particularly useful in suspected localized deposits in the bones. It has been already stated that the *x*-ray picture may show diffuse thickening of bone, atrophy of bone, abscess in bone, or the existence of a sequestrum (*vide* page 648). A sequestrum is shown in Plate XXV, Fig. 1, and at the same time the skiagram (Fig. 2) of the normal knee is shown for purposes of comparison.

Conditions Which May be Confused with Tuberculous Disease of the Knee Joint.

Injuries of the Knee.—Sprain of the joint may cause lameness, with swelling and pain, while the knee is retained in a position of flexion. The symptoms rapidly disappear with appropriate treatment, and thus tuberculosis is excluded; but one must remember that such injuries may predispose to tuberculous disease, especially in sickly children.

Synovitis.—In cases of synovitis of recent traumatic origin there is, of course, no difficulty in determining the diagnosis. In simple synovitis of a non-septic character there is effusion of fluid in the joint cavity, a condition uncommon in tuberculous disease. Here too the amount of thickening of the synovial membrane in proportion to the degree of swelling of the joint is very slight as compared with that in tuberculosis. It must be remembered that chronic synovitis persisting for a lengthy period often becomes the starting-point of tuberculous disease. The acute symptoms which supervene when a focus of disease in the bone suddenly bursts into the joint cavity may simulate acute synovitis, but the previous history of the case will clear up the diagnosis.

Inflammation of Bursæ about the Joints.—Careful examination of the joint will show that it is not involved, there is no fluid within the joint, and the synovial membrane is not thickened.

Acute Epiphysitis; Infective Arthritis.—Here we have a history of sudden onset with marked constitutional disturbance and physical signs of local acute destructive inflammation. Confusion, therefore, with tuberculosis should not arise.

Loose Cartilage in the Joint.—The pedunculated masses of tuberculous tissue to which we have referred, and which may be present in the joint, might be mistaken for loose cartilage. The tuberculous masses are larger, as a rule, and there is a history of gradually increasing disability, while in loose cartilage one usually has a history of sudden attacks of pain with locking of the joint and effusion into the joint cavity.

Charcot's Disease.—The disease is associated with tabes dorsalis, it is often polyarticular, while it is rare to have tuberculous disease in more than one joint. Further, it is more common in adults, and the reverse is true of tuberculosis. Effusion occurs somewhat suddenly into the joint, and destructive processes extend rapidly, producing marked weakness of the joint, with deformity. Pain is usually very slight, and muscular spasm is absent.

Arthritis Deformans.—This is more common in adults, especially when it is of the monarticular form. Creaking may be present on moving the joint. The synovial membrane is not markedly thickened; there are early enlargement of the joint and deformity of bone. Goldthwait has shown the great value of the x-ray photographs in determining the various manifestations of this form of arthritis in both the hypertrophic and the atrophic forms. In the former the irregular conformation of the articular extremity of the bone is demonstrated, and in the latter there are the atrophic changes.

Hæmophilia.—The hæmophiliac joint is produced by hemorrhage into the joint. The history of the patient, showing the fact that he is a "bleeder," in most instances suggests the diagnosis. Fig. 295 is a photograph of such a joint occurring in a boy aged ten years. There may be some inflammatory symptoms accompanying the absorption of the clot.

Rheumatism.—In the child this may be confined to single joints, and then may be mistaken for tuberculous disease. There are, as a rule, marked constitutional disturbances in rheumatism, and the local pain and disability at an early stage are more pronounced. Sooner or later other joints, as a rule, become affected.

Syphilitic Joint.—The form of chronic synovitis which occurs occasionally in syphilis is not likely to be confused with tuberculosis. The history of the case and the progress of the disease enable one to make a diagnosis. Gummata, when they occur about the knee, usually begin in the subcutaneous tissues, and when they appear in the deeper tissue they are found as isolated nodules,

as a rule. The form of syphilitic synovitis to which reference has been made is usually symmetrically developed, so that both knees are involved.

Sarcoma.—A growth of this nature usually begins near one of the epiphyses and may be mistaken for tuberculous disease. If it is periosteal in origin it appears, as a rule, as a more or less localized and irregular bony tumor, but the more centrally the growth is placed the more likely is it to be mis-

Fig. 295.—Affection of the Knee Joint in Hæmophilia, Showing the Enlargement of the Joint which in these Cases may Simulate Tuberculous Disease. The patient was ten years of age. (Original.)

taken for tuberculous disease in the knee. Such growths make rapid progress, however, and their true nature soon becomes evident in that way. In sarcomata certain very characteristic signs may be present, such as eggshell crackling and occasionally pulsation.

Hysterical Joint.—The disability of the joint may simulate tuberculous disease, but the local physical signs of a positive character are absent.

Complications.—The fact that an individual suffering from tuberculosis localized in a joint may become the victim of tuberculous disease elsewhere in the body, has already been discussed in connection with hip disease (page 652). Tuberculous meningitis or disseminated miliary tubercles, pulmonary tuberculosis, etc., may supervene.

Here, too, the importance of recognizing the grave consequences of the occurrence of mixed infection cannot be overestimated. This most frequently results from organisms, other than the bacillus of tubercle, gaining access to a tuberculous abscess. Long-continued suppuration results in destructive septic processes, locally, and general septic infection which frequently has a fatal termination.

Prognosis.—Conservative treatment in average cases affords an excellent prospect of a good functional result. The earlier treatment is instituted and the more efficient it is the better the chances of success. The constitutional

state of the patient necessarily affects the issue. Thus, in weakly children the outlook is not good, and in the face of a strong hereditary history of tuberculous disease one would not give a favorable prognosis. The function of the joint may be preserved in a large proportion of the cases, and this is particularly the case in children, while in the adult the results obtained have not been quite so good. Gibney's statistics, published in 1893, show the results obtained in 300 cases (87 per cent being children). The following results may be tabulated in 242 of the cases treated by conservative methods:

	Cases.	Motion Retained.	Ankylosed.
Where no apparatus was used or where such was inefficient	60	44 (73 per cent)	16
Where joint was more or less efficiently splinted, but not prevented from impact with the ground	145	113 (77 per cent)	32
Where joint was both splinted and protected from jars and mechanical treatment was efficient	37	34 (95 per cent)	3
Totals	242	191 (79 per cent)	51

In 191 of the cases that recovered with a movable joint, 74 had had abscess formation. In the 191 cases also it was noted that the limb was practically straight in 125 (65 per cent). In 49 others the flexion was less than 25 degrees, and in but 16 could the deformity be classed as bad (8 per cent).

The tendency to relapse after apparent cure is not great; thus Gibney found relapse in only 10 cases.

Shortening is less likely to occur than is the case at the hip, but, of course, when it does occur, it may be very much greater, as the growth of the limb in length at the lower epiphysis of the femur is much greater than at the upper, and disease at the knee, leading to destruction of that epiphysis in a growing child, produces eventually great disparity in the length of the two limbs. Fortunately, however, the epiphyseal cartilage is not often destroyed.

The length of time necessary to effect a cure cannot be estimated with accuracy, but it may be stated that, as a rule, from one to two years must elapse after the acute symptoms have disappeared before retentive apparatus can be abandoned.

The mortality in knee-joint disease in Gibney's cases was 13.3 per cent. The cause of death was as follows:

Tuberculous meningitis	6
Exhaustion from prolonged suppuration	14
Pulmonary tuberculosis	3
Dysentery	2
Amyloid disease	2
Intercurrent affections not connected with the disease	12
Shock after excision	1
	40

The prognosis here is affected materially when abscess develops, because the danger of mixed infection is greatly increased, and, under such circumstances, the chances of a favorable issue are greatly diminished.

Treatment.—The principles already laid down for the treatment of tuberculosis in the joints (page 586) are applicable to the knee. The method of applying these principles, however, must of necessity vary in the individual joints because of the difference in structure, in position, and in the function performed by each articulation. Thus, in the knee, the question of the advisability of operative interference with a view to eradicate the disease must be considered more favorably than in the hip, because of the greater ease with which a focus can be reached and the possibility of removing it without damaging structures, which, if destroyed, would interfere with the function of the joint. The general rule is to employ the conservative plan of treatment in children and in those who can properly afford to wait the necessary time for this slower method of obtaining a cure, but in the adult who wishes rapid relief it is often justifiable to cut the morbid process short by the extirpation of the nidus, especially when the disease is brought under observation early and is confined to the bone; or this may be accomplished by erasion (arthrectomy), or excision, according to the degree of involvement of the joint structures in more advanced cases. The fact that tuberculosis of a joint is apt to be more destructive in adults than in youth prompts comparatively earlier operative action in the former. In children it is wise to refrain from operation whenever possible because of the shortening which often results from interference with the epiphyseal cartilages, and because of the lessened possibility of retaining good motion after the joint has been opened.

Conservative Treatment.—The conservative treatment must be guided by the same principles as those which have already been stated in the sections relating to tuberculosis of other joints. Rest is provided by splinting, and protection by the use of a stilting brace. Confinement to bed is not usually necessary for more than a few weeks, and, unless the case is very acute, may be dispensed with.

The most efficient knee splint is the light skin-fitting plaster-of-Paris bandage. It should extend from the ankle, or in very acute cases from the toes, to the groin. In the upper part of the thigh it must be applied tightly and as high up as it is possible to apply it comfortably, so that the longest lever possible may be controlled by the splint, and consequently the least amount of motion permitted. Even when this dressing is perfectly applied, a small amount of motion at the knee can still be carried out owing to the softness of the tissues about the femur, which renders absolute fixation impossible.

The method of application is as follows: A long white stocking, or some tight-fitting seamless shirting, is drawn over the leg. If these are not available, a flannelette bandage is snugly applied. Over this two or three plaster bandages are rolled, the greatest care being taken to avoid wrinkles, and the bandage being made as close-fitting as comfort will allow. It is wise to make the bandage especially thick just above and just below the knee, the points of

greatest strain. Enough of the shirting or flannelette may be left at the top and bottom to be folded back over the edge of the plaster and thus act as a protection against excoriation. If necessary, strips of steel or basswood may be incorporated to strengthen the weak points of the splint. It sometimes happens that the leg is of such a shape that, when the patient stands up, the plaster slides down toward the ground. This may be prevented by applying adhesive plaster to the leg and by leaving one end of this free to be incorporated in the plaster as it is applied. Thus the plaster of Paris is fastened to the leg by means of the adhesive plaster. To prevent the plaster from rotating freely about the leg it should be carefully moulded into the depressions about the patella.

Splints of other materials may be used, such as poroplastic, leather, and so on; they accomplish practically the same purpose, namely, the prevention of motion at the joint.

Fig. 296.—The Thomas Knee Brace.

The best mechanical appliance used for lifting the body weight from the diseased knee is the Thomas brace (Fig. 296). It consists of two upright rods of light steel made to conform roughly to the shape of the inside and outside of the leg. They end below the foot in a leather-shod foot-plate, and above they support a padded ring which fits about the junction of the thigh with the trunk. The ring is of an oval shape, flattened in front and expanded behind to take in the lower part of the buttock. It is attached to the uprights at a lateral and an antero-posterior inclination. The lateral inclination makes it lie about parallel to Poupart's ligament, and thus it receives the body weight throughout its whole circumference, while the posterior dip allows of better support to the tuberosity of the ischium. Fastened to the uprights are transverse leather straps which pass in front of and behind the knee and ankle and serve to steady the limb in the brace. Attached to the highest point of the ring is a strap which passes over the opposite shoulder and prevents the brace from sliding down the leg. The foot-plate is provided with a heel strap exactly like that of a hip brace, for the purpose of holding down the heel and preventing the toe from touching the ground, and, in those cases in which a plaster bandage is not used, traction straps are also attached with the idea of providing more perfect fixation of the knee. When traction straps are used, the adhesive plaster is attached to the leg exactly as in hip disease, except that it does not extend above the

knee. (See photograph of apparatus in hip disease, Fig. 268.) The brace is made so that when it is applied the foot is separated from the ground by two and one-half or three inches. To make the pelvis level again, a corresponding thickness of cork is inserted between the inner and outer soles of the opposite shoe.

As a rule, the aim is to combine the two principles of fixation and stilting. This can very conveniently be done by the plaster-of-Paris bandage worn under a Thomas knee splint. The plaster bandage may be made very thin and light, since practically no strain will fall upon it.

Reduction of Deformity in Early Knee-Joint Disease.—As in hip disease so in knee-joint disease, the deformity is of several varieties. In the early stages, as already pointed out, simple flexion exists, correction of which is resisted by muscular spasm. Later, this flexion becomes a more fixed deformity dependent upon muscular contraction and adhesions. Finally, in neglected cases, where the disease is far advanced, the fixed deformities of flexion, external rotation and posterior subluxation, appear, and an ankylosis of a fibrous or bony character usually adds to the difficulties of correction.

In dealing with deformity maintained by muscular spasm, we have at our command two useful agents in traction and fixation. Traction is employed with a view of reducing the spasm by tiring out the muscles. To accomplish this, the line of pull must be directly in the line of deformity, otherwise the purpose of the surgeon will be defeated. If the pull, for example, be made in the direction of a line joining the heel and ischium, as one might be tempted to do, a lever is produced with the fulcrum at the point of insertion of the hamstring muscles, and the arms of the lever between this point and the knee and foot respectively. As a result of the action of this lever, the intra-articular pressure would be increased and the muscular spasm correspondingly aggravated. We must, therefore, provide for traction in the line of deformity, and for this purpose many schemes have been devised. A convenient one is the traction frame described on page 664 (Fig. 276) for the reduction of deformity in hip disease. To make this suitable for knee-joint cases, the straight frame in which the leg lies is replaced by one which is jointed at the knee. By means of this joint the frame is made to conform to the flexion of the knee. Traction is then applied by the weight-and-pulley apparatus in a line exactly parallel to the lower arm of the jointed frame. When several days have passed, the frame is lowered slightly and the angle at the joint increased until the muscular spasm again is evident. Day by day this manœuvre is repeated, and at the end of a couple of weeks the deformity should have entirely disappeared.

Fixation is also useful in overcoming the flexion. When the case is first seen, a plaster-of-Paris bandage is applied from the toes to high up on the thigh, or even up over the pelvis, in the form of a spica with the knee in the attitude of deformity. The patient is allowed to lie in a recumbent posture for two or three weeks and then the splint is removed. As a rule, when the plaster is

removed one finds that the deformity can now be corrected very materially; usually it rapidly disappears under this form of treatment.

As in hip disease, the traction method may be used when the disease is not very active, but in the more acute cases the fixation method is the better.

When deformity will not yield to such treatment, more forcible measures must be employed. The point to be remembered in applying force to a stiff knee is that it is often easy to produce a posterior dislocation of the joint while endeavoring to stretch the shortened hamstrings. Any forcible means of straightening a knee must therefore provide against posterior dislocation.

The plan suggested by Whitman is an excellent one. The patient is anæsthetized upon an ordinary operating table and rolled over on his face. The

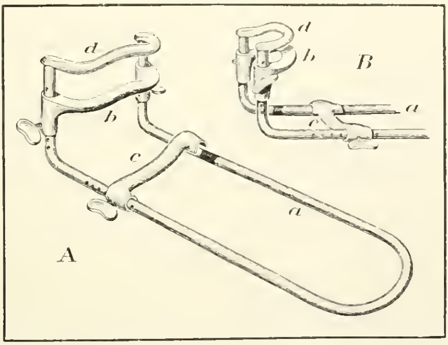

Fig. 297.—The Peters Wrench for the Forcible Correction of Deformity. It is fully described in the text.

patient is raised into the knee-chest position and the operator grasps the leg with one hand just behind the head of the tibia and the other on the ankle. A thick pad or a rolled-up blanket is placed under the leg from the knee to the ankle for the purpose of protecting the knee and shin, and the foot is allowed to hang over the end of the table. An assistant then gently, but forcibly, pushes the thigh with a pump-handle action downward upon the table, bringing it into line with the tibia and correcting all flexion at the knee, the operator in the mean time holding the leg tight against the table. Thus the hand which forces the head of the tibia down on the table prevents all posterior dislocation. This method is better in most instances than that in which the various wrenches are used, as one is able to gauge more accurately the amount and direction of the force employed.

Several excellent mechanical devices have been invented for the forcible reduction of these resistant deformities. The best of these are the wrench devised by Dr. Peters, of Toronto (Fig. 297), and the genuclast of Dr. Goldthwait.

of Boston. Both of these contrivances are levers extending from above the knee to below the foot. The fulcrum is the anterior surface of the lower end of the femur, while the point of pressure is behind the upper end of the tibia. By fastening the ankle in the wrench, the whole leg may be used as a lever and enormous force exerted in breaking down a partially ankylosed joint. The fact that the point of pressure is behind the head of the tibia, close up to the joint, prevents the occurrence of posterior dislocation.

The wrench devised by my colleague, Dr. G. A. Peters, and to which reference is made above, is represented in Fig. 297. It is made of round bar steel five-eighths of an inch in diameter. The apparatus is equipped with two movable bars, one (*b*) upon the upright limbs of the wrench, the other (*c*) upon the horizontal limbs. The bar (*b*), as shown in the figure, is bent toward the body of the wrench and away from the vertical bars to the extent of about an inch and a half, and is provided with two thumb-screws which fit into small depressions on the upright limbs so that it can be set accurately in any desired position. The bar (*c*) is attached by a close-fitting collar to one limb only of the horizontal portion of the wrench, the other end of the bar having merely a concave groove which fits upon the opposite limb. This bar is, of course, also provided with a thumb-screw. By this means the bar can be opened out completely, so as to allow the wrench to be slid over the foot and up the limb to any desired position between *b* and *c*. The bar (*c*) is made slightly concavo-convex on its upper surface, so as to fit the limb, while bar (*b*) is also concavo-convex on its upper surface for the same purpose. It will be observed that the bowing of the bar (*b*) toward the body of the wrench allows the two bars (*b* and *c*) to be practically placed one under the other when in position on the limb, and thus the fullest possible extent of short leverage is permitted. When the wrench is in actual use, further protection may be afforded the parts by placing blocks of "rubber sponge" between the bars (*b* and *c*) and the limb. The length of the wrench is about two feet, and the width between its limbs, from centre to centre, five inches.

Either of the above methods of reduction by force may be used where subluxation has already occurred and where the ankylosis does not seem to be too strong to be broken down. In cases where the ankylosis is too firm, the amount of dislocation will not increase, but it is practically impossible to reduce what has already occurred.

Treatment in the Convalescent Stage.—When the acute symptoms have subsided, the treatment becomes less rigorous. It is the custom with the author to dispense first with the plaster bandage and allow the patient to go about in the Thomas knee brace for a time. After several months have elapsed, if no setback has occurred, the brace is changed to a caliper brace. This is simply a Thomas knee brace, which, instead of extending below the foot, is fastened to the shoe; the upright bars are turned in and fastened to the heel

of the boot. The brace is made about one-half to three-fourths inch too long for the patient, so that at each step part of the body weight is still sustained by the ring at the groin, and the patient's heel does not quite reach the bottom of the boot. When this has been worn for several months longer, and all muscular spasm, heat, and tenderness have disappeared, the brace may be removed. The case must be watched very closely for any return of the symptoms, and if these should occur the first treatment described must be resumed.

Another plan which may be adopted in the convalescent stage is first to remove the Thomas knee brace and allow the patient to walk about with the plaster bandage still in place. Later on, if no acute symptoms appear, this too may be removed. This method answers well in certain cases, but, as a rule, the former of the methods here described is the safer.

Treatment of Abscesses in Knee-Joint Disease.—At any time in the progress of the disease, abscess may develop, and treatment as described on page 677 must be carried out. The development of an abscess must be watched with the greatest care, and if it is extending it must be opened and evacuated; then as much of the tuberculous tissue as possible should be removed by scissors or curette, and the cavity thoroughly wiped out with iodoform gauze; the incision may then be closed with deep and superficial sutures without drainage.

If mixed infection of the abscess cavity takes place from any cause, the aspect of the case immediately changes, and the attention of the surgeon must be directed toward securing efficient drainage. Further operative interference than this is unwise while an abscess exists.

The Reduction of Deformity in Neglected Cases.—When the disease has gone on untreated until the typical deformity has developed, and the limb is fixed in faulty position, operation is required to make the leg straight. The deformity is practically always marked flexion and external rotation, combined with more or less posterior dislocation of the tibia. It is not wise to attempt the treatment of this condition while active disease is still present; and one should wait until all sinuses are closed, before any attempt is made to straighten the limb.

In certain cases where the ankylosis is not very strong and the deformity not too great, the methods described above, for the forcible reduction of the earlier deformities, may be employed. It is, however, often necessary to divide the hamstring tendons in order that reduction may be made possible. This should always be done by way of an open incision, as the danger of dividing the external popliteal nerve is too great to allow of subcutaneous tenotomy. It is a good plan to make it a rule to expose this nerve to view before dividing the tendon. If the operator does this he will have no anxiety about the transient paralyses that sometimes follow the reduction of the deformity.

In those cases in which the deformity is of a firm, fibrous, or bony character, osteotomy will be required to accomplish its correction. The osteotome is

introduced on the outer side of the lower end of the femur about one-half inch above the epiphysis. The instrument is introduced with the edge in the long axis of the limb, and, when pushed through the periosteum, is turned transversely to the line of the femur. The cortex of the bone is then cut through on the outer side and as far across the front of the bone as possible. The femur is here broken through by flexing the leg, and the deformity reduced by traction, while force is applied over the knee. If the deformity is great, supplementary tenotomy of the hamstrings may be required. In extreme cases it is customary to accomplish the reduction of the deformity at two or three sittings, a little being accomplished each time, as the danger of rupturing large vessels is too great to allow of the whole deformity being reduced at once. The method employed is to go about half way the first time, and to do the rest in a week or two, when the tissues have become accustomed to their new attitude. At the same time the external rotation may be partially overcome by rotating the limb inward at the line of osteotomy.

After the correction of the deformity, the limb is put up in a plaster-of-Paris bandage which is retained for about two months. It is prudent, indeed, to keep it on for a much longer time, the patient being allowed to walk about after the first two months. In this way any tendency to recurrence is prevented.

The Bier Treatment.—The method of treating tuberculous arthritis by passive hyperæmia has already been fully described (page 590). This means of dealing with a tuberculous knee may be used with advantage. It may be combined with the various methods recommended for the conservative treatment of the condition.

Wright's Tuberculin.—The value of this method of treatment has been discussed (page 592), as has also the technique of its employment. At present it is being used in the Hospital for Sick Children, Toronto, but it is too early to speak authoritatively as to results.

Constitutional Treatment.—Whatever local treatment is employed and whatever stage of the disease is under observation, one must here, as in all cases of tuberculous arthritis, see to it that the patient is placed in the best hygienic surroundings, and that he has appropriate constitutional treatment.

Operative Treatment.

The operative treatment of knee-joint disease requires careful consideration. A few cases occur in which the presence of localized swelling and tenderness in a condyle or over the head of the tibia, and the absence of synovial thickening, indicate the confinement of the process to the bone; and the diagnosis of localized disease may be further confirmed by the *x*-ray. When this occurs in the inner condyle of the femur it is wise to attempt the total extirpa-

tion of the focus of disease. Should the diagnosis be wrong and the condition eventually prove to be the result of a chronic osteomyelitis or of a tumor, the operation will still prove to have been justifiable, as it constitutes the best treatment of the former and allows an early accurate diagnosis of the latter. If the diagnosis of localized tuberculosis prove correct, the result of operation may be brilliant. The disease may thus be eradicated and a perfect functional result obtained.

Removal of a Tuberculous Focus from the Epiphysis.—In removing a tuberculous focus from the epiphysis of the femur or tibia, care should be taken to avoid opening the knee joint. The incision should be vertical and made laterally where the synovial cavity does not extend up and down, as it does on the front and back of the joint. The incision having been carried down to the bone, the compact tissue is opened up by gouge and mallet and the diseased cancellous tissue removed by means of the gouge or a spoon. The cavity should be flushed thoroughly with an antiseptic solution and wiped with iodoform gauze. Hemorrhage is controlled by pressure. The incision is then closed by a layer suture and dry dressings are applied.

This operation is most appropriate in cases of localized disease in the internal condyle, as the synovial membrane in that locality leaves a sufficient portion of the bone uncovered to permit ready access without opening the joint. The external condyle is not so readily dealt with, and, in disease of the head of the tibia, the epiphyseal cartilage in children is in danger of being damaged.

Healing usually takes place promptly by primary union. The patient is kept in bed for several weeks and then allowed up on a Thomas knee splint, wearing a light plaster bandage. In many cases this apparatus may be dispensed with in a few months, and a cure established in one-third of the time required by the expectant plan.

Operative Treatment of Local Synovial Disease.—Localized synovial disease may be treated upon the same lines as those adopted for localized disease in the osseous tissue. The pedunculated masses which we have described above have been successfully removed by operation. The mass is exposed by a free incision through the capsule and is excised along with a little of the healthy synovial membrane in its immediate vicinity to which it is attached. The exposed portion of the joint cavity is then flushed with sterile normal salt solution. The capsule is sutured with catgut and the superficial wound closed in the usual manner. The after-treatment is similar to that employed after operation for localized caseous deposits, but, if plaster is employed for splinting purposes, it must be divided into an anterior and a posterior portion, which are secured to the limb by bandaging. These should be removed after the first ten days, and sufficient passive movement initiated and maintained to prevent adhesions and a stiff joint.

Operative Treatment of a Diffuse Synovial Disease.—The question of opera-

tion in diffuse synovial disease, and in patients in whom both bone and synovial membrane are involved, must be decided according to the course which the individual case runs. If we find that the disease progresses in spite of efficient expectant treatment, then it is our duty to endeavor to cut the process short by some appropriate operative procedure. Another consideration, to which allusion has already been made, must also affect our decision, namely, that in the adult it may be wellnigh impossible for the individual to afford the length of time necessary to bring about complete cure by expectant treatment, while the disease may frequently be cut short by operation. Operation may also be called for where abscess formation with mixed infection has occurred; partial or complete resection may be necessary to establish efficient drainage.

Arthrectomy.—The term is used to indicate an operation by which all the diseased tissues are removed from the joint. This operation is most applicable to children, and in them is altogether and always preferable to complete excision. In the vast majority of cases excision is unjustifiable in children because of the degree of shortening which must necessarily follow the destruction of the epiphyses. On the other hand, arthrectomy is seldom advisable in the adult because an unstable joint is apt to result, and it is far better, in most instances, to proceed at once to complete excision and aim at firm bony ankylosis. In the child, although arthrectomy may leave a somewhat unstable joint, yet, by appropriate splinting, after eradication of the disease, the child may be tided over the period of active growth of the limb, and thus, with a minimum amount of shortening, a good result may eventually be obtained. Occasionally, though we must admit rarely, a good, useful, movable joint is obtained after arthrectomy.

Excision.—The results of complete resection of the knee joint for tuberculous disease in the adult have been eminently satisfactory. (See article on "Excisions" in Vol. IV.) The object aimed at is to procure complete eradication of the disease and to secure firm bony ankylosis. Various methods are employed for excising the knee; of these the author has found that introduced by Kocher, of Berne, the most generally useful and satisfactory. This method of incising and opening the knee joint may be employed for excision, for arthrectomy, or for simple arthrotomy. The operation aims at preserving the extensor apparatus of the joint intact. The incision begins over the vastus externus, a hand's breadth above the upper margin of the patella, and passes first vertically downward upon the outer side of the patella, separated from that bone by a finger's breadth; below the patella it is carried with a slight curve inward, and ends on the anterior border of the tibia, having passed beneath the tibial tuberosity. The skin is divided and the strong fascia lata is exposed. This fascia is divided, and will be found specially thick in its lower part. In the upper portion of the wound there will appear the lateral margin of the vastus externus muscle, which must be divided;

below this is the outer surface of the joint capsule, while in the lower end of the wound will be found some fatty tissue and the lateral margin of the ligamentum patellæ; below this, again, one cuts directly upon the bone as one passes below the tubercle of the tibia. By means of the chisel one proceeds to separate the tibial tubercle with the periosteum and the attached ligamentum patellæ, thrusting it toward the inner side. On cutting through the vastus externus, one exposes the external condyle and opens up very freely the recess under the quadriceps extensor cruris. Lower down, the anterior extremity of the semilunar cartilage is cut away from the tibia without detaching the capsule from it, and it, along with the capsule, is separated from the upper surface of the tibia. One draws inward with sharp hooks the ligamentum patellæ, and, pulling this to one side, one separates the anterior attachment of the internal semilunar cartilage, in front of the crucial ligament, and the capsule, together with the periosteum, is separated, as on the outer side beneath the meniscus, from the cartilaginous internal condyle of the tibia. Now one can dislocate the patella inward. By more and more flexing the joint and loosening the capsule from the tibia below, internally and externally, extreme flexion can be obtained. Next, one must sever the attachment of the crucial ligaments from the spine of the tibia close to the bone as far as the posterior attachments of the menisci. These, with the crucial ligaments, will be separated from the tibia as far as the posterior margin of the bone.

If one must now go on to complete resection, then the crucial ligaments must be separated from the intercondyloid fossa of the femur; as a result of which these ligaments, together with the menisci, the posterior wall of the capsule, and the periosteum, remain in a mass situated posteriorly and still attached to one another. The capsule must then be dissected off the femur. If the lateral ligaments are to be preserved, they must be separated from the epicondyles subperiosteally, and the femur is then sawed with a convex surface, and the tibia with a concave surface, after similarly loosening the capsule with the periosteum from its posterior margin.

When all hemorrhage is checked and the anterior tubercle of the tibia is fixed in position by silver wire, or a nail, the wound is closed by interrupted sutures without drainage. The limb is then secured in a plaster splint until firm bony ankylosis has occurred. It will be found advisable in many cases to remove the patella entirely if complete resection is performed; this bone is frequently diseased and no useful object is served in preserving it when we are aiming at bony ankylosis after resection.

Amputation.—This operation is called for only when the disease is so extensive and progressive that the limb must be removed in order to save the life of the individual.

Tuberculous Disease of the Ankle Joint, Tarsus, and Metatarsus.—Tuberculous disease occurs in the ankle joint with much less frequency

than in the hip or knee. During adolescence and in young adults the disease is much more common than in children. In fact, tuberculous disease of the ankle is a comparatively rare disease in childhood. In the Hospital for Sick Children, Toronto, for example, where the patients are all fourteen years of age and under, there were only 9 cases of ankle-joint disease out of 315 cases of tuberculous arthritis (*i.e.*, about 3 per cent). Tuberculous disease of the tarsus is more common than that of the ankle alone. In the Children's Hospital series the tarsus was affected twice as often as the ankle joint. It would appear that

Fig. 298.—Section through the Foot and Ankle of a Child Nine Years of Age, showing the epiphyses of the tibia, of the os calcis, and of the second metatarsal bone. The osseous arch of the foot is apparent. (Original.)

about a similar proportion exists at all ages, as in Cheyne's series the tarsus was affected forty times, while the ankle was involved only twenty-three times.

Anatomical Considerations.—For our purpose here only brief reference need be made to certain of the anatomical features of the ankle and foot. Movement at the ankle joint is restricted almost solely to dorsal and plantar flexion. There is a slight amount of lateral movement possible when the joint is in a position midway between extreme dorsi-flexion and extreme plantar flexion. The lateral movement is permitted while the foot is in the attitude mentioned because while in that position the widest part of the astragalus has passed from between the tibia and fibula, and the ligaments are more relaxed than in the full plantar flexion, so that lateral movement to a limited extent is under

such circumstances possible. When full dorsal flexion is brought about, the anterior and widest part of the superior articular surface of the astragalus passes between the fibula and tibia and even to a slight extent separates the fibula from the tibia sufficiently for its accommodation.

In the mechanism of the foot, the existence of a transverse as well as a longitudinal arch must be remembered, and, in dealing with diseased conditions of the foot, these must be preserved as far as possible; these arches are maintained by strong ligaments, by muscles, and by the plantar fascia. The chief movements between the tarsal bones are those carried out in inversion and eversion of the foot. These movements are very limited in extent between any

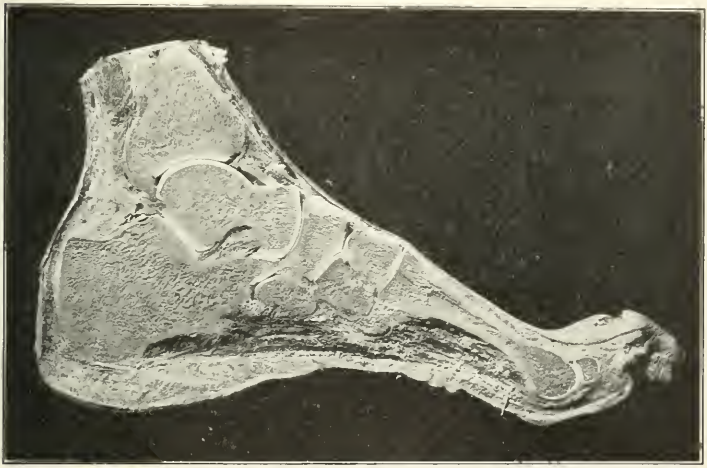

FIG. 299.—Section through the Foot and Ankle of an Adult, Showing the Construction of the Arch of the Foot at the Instep. (Original.)

two of the bones, but the mobility of the foot as a whole is considerable. The strength of the joints between the bones of the foot is chiefly ligamentous; there is little or no osseous strength; that is to say, the articular surfaces do not fit into or grip one another, but for the most part are plane surfaces which are kept in contact by ligaments. These articulations are also greatly strengthened by the insertion of the muscles which are attached to and carry out the various movements of the foot. Figs. 298 and 299 show the construction of the arch of the foot at the instep in the child and in the adult.

The bones of the foot and ankle are made up of cancellous tissue, with but a very thin covering of compact tissue (*vide* Figs. 298 and 299). The articular surface of each bone, too, is seen to be provided with quite a thick layer of

articular cartilage. Lastly, attention should be directed to the epiphyseal cartilages. Those at the ankle are shown in section in Fig. 300. It will be observed that the epiphysis of the fibula is placed lower than that of the tibia, and that the epiphyseal disc of cartilage of the fibula is exactly on a level with the superior articular surface of the astragalus. The epiphysis of the os calcis is seen in Fig. 298. It exists upon its posterior extremity.

Etiology and Pathology.—The same etiological factors are at work here as elsewhere, in the production of tuberculous arthritis, and they have already been fully discussed. In the ankle, however, chronic sprain is a more frequent

FIG. 300.—Sections through the Ankle Joint of a Child Nine Years of Age, Showing the Epiphyseal Cartilages of the Tibia and Fibula. (Original.)

cause of tuberculous disease than is the case in the other joints. For this reason one should always look upon a sprained ankle as serious, particulary in an individual predisposed to tuberculous disease.

The disease is said to be more frequently primary in the synovial membrane when the ankle joint is affected, and as a rule primary in bone when the tarsus is the seat of disease. Fig. 248 (p. 577) is a good illustration of a sequestrum in the anterior part of the astragalus in an old case of tuberculous disease; the condition of sclerosis of the bone forming the walls of the cavity in which the sequestrum lies is worthy of note. Fig. 301 is a photograph of a frozen section through the foot of a lad seventeen years of age, who ten years previously had had his right ankle joint excised for tuberculous disease. One may observe that complete bony ankylosis has occurred between what remained of the

astragalus and the lower portion of the tibia. While this formative process was going on, the disease progressed in another portion of the tarsus and became extensive and septic, so that amputation had to be performed.

When the ankle joint is the seat of disease, the astragalus is much more often primarily involved than is the tibia or the fibula. Of the tarsal and metatarsal bones the os calcis is most frequently affected, then the first metatarsal, then the astragalus, and lastly the scaphoid and the internal cuneiform. When tuberculous disease of the ankle or tarsus occurs, it is remarkable how the tarsal bones which are not the seat of disease show rarefying osteitis. Plate XXVI,

FIG. 301.—Section through the Foot Showing Complete Bony Union between the Tibia and the Astragalus. Excision of the ankle had been done ten years previously for tuberculous disease. (Original.)

Fig. 1, is an x-ray photograph from a case of tuberculous ankle in which, in a patient twenty years of age, there had been extensive destruction of the ankle joint by tuberculous disease. The skiagraph shows the marked condition of bone atrophy in the tarsus; the compact tissue covering each bone shows up as if it had been pencilled in the picture, while the cancellous tissue shows a diffuse, blurred appearance in marked contrast to the healthy bone, as seen when Fig. 1 of Plate XXVI is compared with Fig. 2 of the same plate, the latter being a skiagraph of the healthy foot.

Another feature of tuberculous disease of the ankle and foot is the frequent occurrence of abscess. Chronic abscess is much more common in ankle-joint disease than in the case of either the knee or the hip. Where mixed infection

occurs and the abscesses open, the whole foot may become riddled with septic sinuses.

The synovial sheaths of tendons about the ankle joint may be affected, and thus a condition of tuberculous teno-synovitis is not an unusual complication.

Symptomatology.—In the early stages of the disease the disability is slight. The patient complains usually of aching and discomfort after walking, and therefore commonly at night. After a time, swelling and pain manifest them-

Fig. 302.—Tuberculous Disease of the Ankle Joint in a Child Three Years of Age, Showing the Characteristic Enlargement of the Joint in the Attitude of Equino-Valgus. (Original.)

selves. Weight can no longer be borne with comfort, and lameness results. The foot gradually assumes a position of a more or less marked degree of equino-valgus, and the patient bears his weight partly on the heel and partly on the inner border of the foot. The swelling in primary synovial disease may appear anteriorly on either side of the extensor group of tendons, or it may be present posteriorly on either side of the tendo Achillis, more rarely is it perceptible below the malleoli. Sooner or later, however, the swelling becomes uniform and the characteristic fusiform shape of the tuberculous joint makes its appearance. Fig. 302 shows this condition in a child three years of age, in

whom tuberculous disease followed a sprain nine months previously. The normal depressions about the joint become obliterated and the bony prominences are no longer visible.

There is limitation of movement, so that the voluntary degree of dorsal or plantar flexion cannot be carried out, and, while a limited amount of passive movement may be produced without discomfort, yet extreme dorsal or plantar flexion is resisted in a characteristic fashion by muscular contraction. The joint is usually extremely sensitive to any sudden movement, and pain on pressure, particularly over the malleoli, is frequently observed. Slight injuries in the early stage of tuberculous disease of the ankle usually cause an exacerbation of the symptoms, and acute pain may occur which subsides on resting the joint. Increased heat may be observed when the diseased joint is compared with that of the sound side.

Muscular wasting of the calf and thigh is a characteristic feature of the disease, as is wasting of the related muscles in tuberculous arthritis elsewhere.

When abscesses form, they usually come to the surface anteriorly and laterally. If mixed infection is allowed to occur in these abscesses, the trouble at once becomes grave, and septic processes induce much more rapid destruction of the structures in and about the joint. Eventually many sinuses may burrow in the tissues in various directions.

When the disease is primary in the astragalus, an abscess may form and come to the surface outside the ankle joint, but more frequently the disease spreads from the astragalus and invades either the ankle joint or the astragalo-scaphoid joint.

Diagnosis.—It is sometimes difficult to determine the diagnosis as between the stiffness and pain which occasionally exist after a severe sprain, and beginning tuberculous disease. This is especially the case in view of the fact that the latter condition not infrequently succeeds the former. Where it is merely a case of adhesions after injury, the condition manifests itself immediately after retentive apparatus has been removed, the foot being comfortable when at rest, but painful when weight is borne upon it. In tuberculous disease, on the other hand, the discomfort is often most marked at night, and the condition tends to become progressively worse. Flat-foot may be excluded in very much the same way; it may also be noted that in this affection the pain and discomfort are localized at the mid-tarsal joint. In flat-foot the swelling will disappear rapidly when rest is provided, and an *x*-ray photograph will often confirm the diagnosis when tuberculous disease is present.

Septic arthritis runs a much more rapid course than tuberculous disease, and the symptoms are acute. Rheumatism may, as a rule, be diagnosed by the history of the case; monarticular rheumatism is rarely found in the ankle joint. Similarly, arthritis deformans is rarely confined to the ankle, but the possibility of its occurrence must be borne in mind.

Prognosis.—In children tuberculous disease of the ankle is frequently recovered from with complete functional result. In the adult, the prognosis is not nearly so good; abscesses often become the seat of mixed infection, and diffuse septic trouble in the foot not infrequently supervenes. The prognosis in the adult is therefore less favorable than in the child.

Treatment.—The principles involved in efficient treatment here are those already fully discussed in the case of the hip or the knee. When a diagnosis of tuberculous arthritis has been made, it becomes necessary, in the early stage of the disease, to put the joint functionally at rest. This is best accomplished by recumbency and by the application of a well-fitting plaster-of-Paris fixation splint, applied from the toes to a point immediately below the knee. Of course it is not possible to apply the principle of traction to the ankle joint, as was advocated in the knee and hip.

If it is possible to locate definitely a primary focus of disease in the bone, while the joint itself is not yet invaded, then one should remove it by operation without opening the ankle joint. The recognition of such a deposit is rarely possible at the ankle, however, and one should proceed with caution, because it appears that partial and incomplete operations are often responsible for the protraction of the disease, with greater destruction of tissue and greater interference with function than would have occurred had different treatment been adopted.

It being assumed, then, that treatment by fixation and recumbency has been adopted, the progress of the case must be carefully watched, and, when pain and tenderness and all symptoms of acute trouble have disappeared, the patient may be permitted to move about, but on no account should he bear his weight upon the affected limb. The desired result may be secured by the use of crutches, with perhaps some increased thickness of the sole of the boot on the sound side. Another way of effecting our purpose is by using the Thomas knee brace already described in the section relating to the treatment of tuberculous disease of the knee (page 703, Fig. 296).

In connection with this expectant form of treatment, and in fact under all circumstances where fixation is employed, it is essential to see that the position of the limb at the ankle is maintained correctly. Deformity once thoroughly established is often difficult to correct, because of the infiltration of the tissues by inflammatory material and the pain caused on manipulation. The foot must be dorsi-flexed to a position such that the angle of flexion is less than a right angle; the foot may also be slightly supinated to prevent the valgus deformity which tends to occur. If this cannot be accomplished when the patient comes under observation, then it is our first duty to correct the faulty attitude which has been already assumed. This may be accomplished by applying a plaster splint to the limb in its faulty position; and while it is thus splinted, the patient is kept recumbent. After, say, two weeks the plaster is removed,

and then, as a rule, we find that correction of the faulty attitude is possible, the acute symptoms having subsided and muscle spasm no longer existing. If some resistance is still encountered, then in all probability gentle manipulation will effect our purpose, but in certain cases forcible correction under an anæsthetic is necessary. Tuberculous disease involving the ankle joint, when treated by expectant methods, most frequently results in ankylosis more or less complete, and hence the necessity of fixing the joint in the position indicated. If this were not done, the pointing of the toes and the valgus deformity would render progression painful and in some instances wellnigh impossible.

The Bier treatment of passive hyperæmia may well be combined with the conservative methods of splinting which we have just described. The details of this treatment have been described on page 590. The bandage may be applied around the thigh, and the treatment maintained for one hour daily.

The length of time required for effecting a cure will necessarily vary in different cases, but, if the case should run a favorable course under expectant treatment, then from one to two years will elapse before we can safely allow the patient to walk upon the affected limb. A general rule may be laid down that at least six months must elapse after all symptoms of active disease have disappeared before the patient is permitted to move about without a splint.

If the disease continues to progress unfavorably under expectant treatment, then operation is indicated. In the case of the ankle joint, operative treatment is resorted to much earlier than in either the hip or the knee, because we find that, in these operations upon the ankle, an excellent functional result is obtained in the vast majority of instances, and in fact a very much better result than is possible under expectant treatment in cases in which progressive disease has brought about extensive implication of the structures about the joint.

The operation of most service is excision of the astragalus. This allows free access to the joint and permits one to remove all diseased tissue very thoroughly. It has a distinct advantage over excision of the joint because in the latter case bony ankylosis must occur, while after taking out the astragalus alone a movable joint is secured and a much better functional result obtained. The operation is best performed by the method of Kocher, of Berne, which is as follows: A longitudinal incision is made over the antero-external aspect of the ankle, beginning a hand's breadth above the ankle joint on the posterior margin of the fibula, and, after it has been continued vertically to the lower end of the fibula, it is curved forward under the external malleolus and terminated at the tubercle at the base of the fourth metatarsal bone. The incision below lies to the outer side of the extensor muscles and the branches of the musculo-cutaneous nerve. The sheaths of the peroneus longus and brevis are exposed and slit up to the upper angle of the wound. The tendons of these muscles are then divided, but only after two silk ligatures have first been passed through each so that they may be subsequently secured for suture. The three portions of the external lateral liga-

ment are divided close to where they are attached to the external malleolus. The extensor tendons, along with the vessels and nerves, are detached by the periosteal elevator from the anterior aspect of the joint, and the astragalus is bared. The capsule is separated from the anterior aspect of the tibia as far as the internal malleolus, and a similar separation is effected posteriorly. The foot is now forcibly dislocated inward over the internal malleolus, so that the upper articular surface of the astragalus looks downward and the sole of the foot upward. If the external malleolus is the seat of disease, it may be broken in the process, but under such circumstances no harm is done. The astragalus may now be removed after the capsule of the astragalo-scaphoid joint has been cut through and subsequently raised from the os calcis by a periosteal elevator, and after the calcaneo-astragaloid ligament has been divided. The joint should now be carefully inspected, and any focus of disease in the tibia or fibula removed: the diseased synovial membrane or ligament must be similarly dealt with. The peronei tendons are then sutured after the foot has been brought back into its proper position, and the wound closed in the ordinary way. The wound is dressed, and the foot, in a correct position, is then secured in a plaster splint. It is advisable to carry the foot well back before securing it in the plaster; this will prevent any tendency of the malleoli to slip off the posterior part of the os calcis, and will also fill in the space that is left at the rear of the scaphoid bone.

Excision of the ankle joint may be performed after the joint has been exposed in the manner advocated by Kocher, as just described. In addition to the arguments already advanced against a formal resection, it should be observed that in children such an operation would necessarily remove the epiphyseal cartilages of the tibia and fibula, thus interfering with the growth of these bones.

Chronic abscesses developing in connection with ankle-joint disease should be treated in the same manner as are similar conditions in the knee and hip. Every effort must be made to prevent mixed infection, and, if the abscess is opened, it should be curetted and stitched up without drainage, so that primary union may occur. Where septic sinuses are discharging, the main principle to be held in view in treatment is the necessity of efficient drainage; for this purpose it may be necessary to remove the astragalus.

Amputation.—This is considered only when the disease is very extensive and when destructive processes have advanced in septic cases to such an extent that there is no longer any prospect of saving a useful foot. Syme's amputation is the most desirable form of operation, but in extensive disease it may be impossible to obtain sufficient healthy tissue to carry it out. Under such circumstances it is necessary to amputate higher up the leg.

Disease of the Tarsal Bones Independently of Each Other.—Disease of the tarsal bones individually is not uncommon. The os calcis is the one most frequently affected, then comes the astragalus. These two bones afford slightly more than fifty per cent of the reported cases of tuberculous tarsal-bone affec-

tions. Less than fifty per cent of such cases are those in which the remaining bones of the tarsus are affected; of these the cuboid is the most commonly implicated, and then the scaphoid; lastly the cuneiform bones, which are least frequently the seat of disease.

The synovial cavities are so extensive between these bones and the bases of the metatarsals, that disease spreads rapidly and extensively whenever a joint cavity becomes invaded. Fortunately, the disease not infrequently comes to the surface through the thin veneer of compact tissue which covers the bone, and does not perforate the comparatively thick layer of articular cartilage. When the joint cavity is invaded, it probably, in the majority of instances, occurs indirectly through the synovial membrane, which may be the primary seat of disease or may be affected by extension from the bone.

Primary disease of the astragalus has already been dealt with in connection with the ankle joint. We have seen that the ankle joint may become invaded from such a focus. Similarly, the subastragaloid joint—the calcaneo-astragaloid articulation—may become invaded from such a focus, or the astragalo-scaphoid joint may in like manner become involved.

In the case of astragaloid disease the symptoms are very similar to those described for the ankle joint. The swelling is, however, at a somewhat lower level, while the ankle joint itself is obviously not affected.

The treatment in astragaloid disease is expectant, along lines already described for the ankle; but should the disease continue to progress, then excision of the astragalus by Kocher's method should be carried out.

Disease in the astragalo-scaphoid joint may be reached by an incision directly over the articulation, should it be thought wise to operate for trouble situated in that locality.

A primary focus in the os calcis is the most common lesion in tuberculosis of the tarsus When it can be located it is best to remove it by operation. This may be done by an internal or an external incision planned to reach the deposit in the most efficient manner. The bone is readily accessible, either by an external or an internal incision, preferably the latter. The soft parts are separated from the bone by a periosteal elevator, and the focus of disease removed by the gouge in the usual manner. The wound is closed without drainage, and the foot splinted in plaster of Paris in good position.

In extensive disease of this bone complete removal of the os calcis may be called for. This is accomplished through an incision which is carried horizontally around the foot a finger's breadth above the sole. It begins at the base of the fifth metatarsal bone and passes backward around the heel and along the inner side of the bone for an inch and a half. This is carried through the skin and fascia. A vertical incision in front of and parallel to the tendo Achillis may be added on the outer side. The soft structures are separated from the bone by the periosteal elevator, and the tendo Achillis is divided close

to the bone. The bone must be cleared by careful dissection so that important structures, particularly in the neighborhood of the sustentaculum tali, may not be damaged. Its various ligamentous connections are severed and the bone is removed. The wound is carefully inspected for any diseased tissue, which, if found, must be dissected out. The cavity left is a large one and it may be thought advisable to drain for, say, forty-eight hours, to get rid of blood and serum which might collect and interfere with union. A light plaster-of-Paris splint should be applied. This can be readily taken off for the purpose of removing the drain, and a more substantial plaster splint substituted.

The patient recovers from such an operation with a useful foot. It is about half an inch shorter than its fellow, but this is compensated by a pad of felt or India rubber in the sole of the boot, and the individual is able to walk and to transmit his weight through the foot without discomfort.

The cuboid, scaphoid, or cuneiform bones may be removed individually for localized foci of disease. Such cases, if the operation is successful in eradicating the disease, recover with a good functional result. The cavity left after removal of the bone is soon filled with tough fibrous tissue, or possibly by some osseous formation, and the stability and usefulness of the foot are thus maintained.

Diffuse Tuberculous Disease of the Tarsus.—Where the tarsal bones and the synovial membrane are extensively involved, amputation is necessary in most instances. Where mixed infection has occurred and a septic condition exists, then here, as elsewhere, efficient drainage must be secured; and if removal of the bone is necessary to effect this purpose, then the bone must surely be sacrificed. But where the course of the disease has been very chronic, where there has been no septic trouble, and where the patient is in other respects a healthy subject, the operation of partial or complete tarsectomy may be undertaken.

Mikulicz's operation of complete tarsectomy consists in dividing the bones of the foot through the bases of the metatarsal bones, or, if the position of the disease warrants it, the cut across the bones of the foot may be through the distal part of the tarsus. The bones of the leg are divided immediately above the ankle joint. The incisions are so devised that along with the os calcis the skin and soft structures about the heel are removed. The anterior part of the foot is then brought into a straight line with the leg, and the sawed surfaces of the leg bones secured by silver wire to the sawed surfaces of the metatarsals or the remains of the tarsus, as the case may be. The wound is closed and the limb efficiently splinted. The splinting should be arranged so that the toes are pressed forward to form a right angle with the metatarsus.

The results of Mikulicz's operation have not been eminently satisfactory, and in most instances a more useful member may be secured by amputation and the use of an artificial foot.

When the disease is in front of the mid-tarsal joint, partial tarsectomy may be performed. This may be accomplished by two lateral incisions, the outer one being rather dorso-lateral in position. These incisions are carried down to the tarsus. The soft structures are separated from the bone in the usual way, and the tarsus is sawed through across the neck of the astragalus, the os calcis being divided in the same plane. Another transverse saw-cut is made across the heads of the metatarsal bones, and the anterior portion of the tarsus, along with the bases of the metatarsals, is removed. All diseased tissue is dissected away and the wound closed with or without drainage, depending on the amount of subsequent oozing which is anticipated in the individual case. Wiring is not necessary, but the foot is brought into good position and secured in plaster. As healing takes place, the various structures contract and shorten, and a very good functional result is obtained, with, of course, a greatly shortened foot.

While little can be said in favor of complete tarsectomy, there can be no doubt that partial tarsectomy, in suitable cases, yields a good result, and, when the disease can be eradicated by this means, it is preferable to amputation.

In the presence of numerous septic sinuses, with extensive infiltration of the soft tissues, Syme's amputation at the ankle joint is the better operation.

Tuberculous Disease of the Metatarsals.—In fifty per cent of such cases the disease is situated in the first metatarsal bone, and usually at the base. When it can be located there it should be removed by operation. If the focus of the disease is in the base of the bone, the incision should be made along the axis of the affected metatarsal just external to the extensor tendon. Beginning over the internal cuneiform bone above, it should extend down to about the centre of the bone. The soft parts are separated and the bone is severed by cutting-pliers. The ligamentous connections are then divided and the diseased bone removed. The wound is dressed and the foot splinted.

The results after such an operation are excellent. Dense fibrous tissue replaces the bone removed, and a perfect functional result is obtained.

Metatarsal bones other than the first may be similarly treated when localized foci of disease are recognized.

Tuberculous Disease of the Phalanges of the Foot.—The condition of "spina ventosa" is occasionally met with in the foot, especially in children. This affects, as a rule, the phalanges, but now and then one of the metatarsal bones is similarly involved. The metatarso-phalangeal or the interphalangeal joints may also become involved.

These cases are best treated by operation. In children the bones may be cut down upon and thoroughly curetted; or resection of diseased joints may be undertaken, and thus the disease is not infrequently eradicated successfully. Should this procedure not prove successful, then amputation of the digit or the diseased portion of the digit should be performed, and, in the adult, amputation

is advocated as the better procedure for the primary operation. An exception may be made of the metatarso-phalangeal joint of the great toe, where in all cases excision of the joint should be attempted before amputation is resorted to, because of the importance of preserving the great toe as a basis of support in the foot.

Tuberculosis of the Long Bones of the Extremities.—Reference has already been made to the fact that tuberculous disease may affect the long bones at points distant from the joint (page 579). We have elsewhere described the disease as it appears in the long bones of the foot and hand. The pathology of the condition has been discussed. A chronic periostitis may be the first manifestation of the disease, and extensive destruction of bone may result, or the disease may begin in the medulla of the bone, contituting a tuberculous osteomyelitis. Chronic abscess in bone most commonly develops near the articular extremity; in such cases the x-ray may prove a valuable aid to diagnosis. Fig. 254 illustrates a chronic abscess in the lower end of the right radius, as shown by this means. The patient was fifteen years of age and complained of pain, swelling, and stiffness of the right wrist: the symptoms of trouble had existed for three months. An operation was performed and the abscess opened after chiselling through the compact tissue.

The disease is very insidious in its onset and runs a chronic course. Pain and disability constitute the early symptoms. The pain is most troublesome at night. Local tenderness is detected on manipulation, and swelling at the seat of trouble gradually develops. Abscess may form, and, where mixed infection occurs, the usual sequence of events will be noted, involving long-continued suppuration and the persistence of septic sinuses.

Treatment.—The general principles of treatment laid down for tuberculous arthritis are applicable in the cases now under consideration. Expectant treatment is to be advocated in the early stage of the disease; the part is to be kept at rest by suitable splinting.

If progress toward recovery is not made, then the bone must be laid bare and the tuberculous disease removed by curetting with a sharp spoon. If there has been no mixed infection the wound should be closed without drainage. If the wound becomes septic, then free drainage must be secured and the wound packed with sterile gauze and allowed to granulate.

The treatment of chronic abscess and the treatment of septic cases must be carried out along the lines already advocated for such conditions in connection with tuberculous arthritis.

WOUNDS OF JOINTS.

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GENERAL CONSIDERATIONS.

Wounds of joints may be conveniently considered as belonging to two general classes, *i.e.*, those without solution of continuity of the skin, and those in which there is a wound of the skin associated with lesions involving the joint. The former class includes sprains, lacerations (primary and secondary), crushes, tearing of ligaments, loosened cartilages, and traumatic effusions. The second class embraces gunshot, incised, punctured, lacerated, and crushed wounds.

Sprains.—Much uncertainty has attached, and always will attach, to the meaning of the word "sprain." It is one of those indefinite words which have been introduced into medical nomenclature and which it is impossible to define exactly. It may be used to cover many varieties of injury to a joint in which the skin is unbroken, or it may be reserved for those slight cases in which no definite lesion can be demonstrated. "The ligaments may be torn across, or wrenched off the bone; the muscles may be lacerated; the tendons displaced bodily from their grooves; the discs of cartilage which are present in some joints between the bones, forced out from their position; the joint cavity filled with blood, and so much extravasated into the tissues that the discoloration may reach from the ankle to the knee; in short, the tissues may be torn and bruised as extensively as in a dislocation." (Moullin: "On Sprains.")

Since it is very difficult to define accurately what a sprain is, it would seem the part of wisdom to eliminate the word, so far as possible, from those used in describing an injury to a joint. Nevertheless, owing to the fact that this term has been in such general use, it can probably still be employed for designating those slight and trivial injuries in which there exists no more serious lesion than an evanescent interference with the function of a joint—a twist without evidence of laceration of ligaments or any other appreciable lesion.

It may be laid down as an axiom that sprains are produced either by a sudden movement of a joint in a direction contrary to the normal, or by a movement which causes the normal range to be exceeded. Thus, a force which compels a lateral movement of the ankle may produce a sprain, or hyperextension or overflexion may result in a similar impairment of function. In

either case the brunt of the traumatism is borne by the ligamentous structures, and the disability is in proportion to the amount of damage sustained by these bands of unyielding tissue. The condition ordinarily designated as a "sprain" is, in all probability, due to stretching of the ligaments without any appreciable tearing or actual laceration of their fibres. The author believes that the word "sprain" should be limited to this class of cases, because, if it be not so limited, one cannot, when one encounters the term, form a definite idea of the nature of the injury to which it is applied.

There is a special predisposition on the part of certain people, usually women, to the occurrence of sprains, particularly of the ankle. In these individuals there seems to be an unusual laxity of the tissues that support the joint, an increased or abnormal range of motion, which permits the joint to be caught off its guard. Under these circumstances an apparently trivial traumatism may lead to serious loss of function.

Lacerated Ligaments.—Should extravasation of blood occur or marked increase in the range of motion ensue, one may be sure that there must have been some tearing of the fixation structures in order to produce these results; and when this has occurred the condition should be designated as one of lacerated ligaments. One can form a fairly clear idea as to which ligaments are injured by noting the direction of the force and the abnormal movements present after the injury.

In many of the cases of fractures in the vicinity of joints—*e.g.*, Colles' and Pott's—laceration of the ligaments is a very important feature of the injury. These lacerations may be termed secondary or complicating, in contradistinction to those which occur without fractures and are called primary.

Contusions.—Contusions of joints differ from the preceding in that the injury is the result of direct violence, the effects, however, being very similar. Contusions vary from light bruising to an injury complicated by extensive crushing of the joint structures.

Floating Cartilages.—Floating cartilages, found usually in the knee joint, may be the result of injury; or, by becoming caught between two articular surfaces, they may be the cause of injury to the joint in which they are found.

Hysterical Joints.—One must ever remember the possibility of simulated and of hysterical diseases of a joint. The entire joint malady may be of this nature. The patient may develop hysterical symptoms during the course of repair of an injured joint, or they may follow in the wake of an injury, the symptoms imperceptibly shading off into those of general hysteria. In these cases there is almost always a degree of nervous apprehension present whenever any attempt is made to examine an injured joint, but as a rule quiet persistence and deliberate handling of the parts will dissipate the tendency to spasmodic contraction of the muscles that control the injured region. In some cases, particularly in children, any attempt at handling the injured limb

is met by such nervous manifestations as to preclude a satisfactory scrutiny. The use of an anæsthetic is frequently necessary in order to obtain an intelligent conception of the nature of the injury. One should never be content to guess at the condition, but should resort to the use of an anæsthetic in all cases in which a satisfactory examination is otherwise impossible.

During the course of treatment of an injured joint one sometimes encounters a case in which the manifestations of pain are much more pronounced than under ordinary circumstances. Such cases should be very carefully examined for overlooked fractures or other severe injuries. When these are not found, the unusual pain may be ascribed to a neurotic origin and treated accordingly. The varying susceptibility to pain in different individuals must also be taken into account.

It is a suspicious circumstance when an individual, who is receiving pecuniary benefit during his illness, complains of long-continued and severe pain in an injured joint in which no adequate evidence of lesions of such a degree of severity can be found. At the same time one must never permit one's self to assume that the pain is simulated, but should make every effort to discriminate between the true and the false claims.

Neurotic individuals sometimes present very remarkable symptoms after an apparently trivial injury. It usually happens, however, that these patients either overdo the matter or present a set of symptoms which do not harmonize with those which should immediately follow the particular injury. The author has but recently had under his care a young girl, nine years of age, a badly spoiled child, who fell downstairs and injured her leg. No improvement in her symptoms took place for more than a year. She would scream with pain when the leg was touched, and she walked with a very decided limp. She had been most carefully attended, but no signs of improvement were manifest. Six weeks of isolation in a hospital with proper attention to discipline restored her to a normal condition. Many similar cases occur.

Pathology.—The pathological changes which take place in a sprain are problematical, because the injury is not susceptible of either operative or postmortem demonstration. No doubt, the brunt of the injury falls upon the ligaments, these structures being either overstretched or their fibres but slightly torn. In some cases the joint surfaces may also be bruised.

Symptomatology.—Sometimes a sprain produces practically the same set of symptoms as a fracture, especially when the latter is near a joint. The most characteristic symptom is sudden pain, this manifestation almost invariably accompanying the infliction of the injury. In a simple wrench of a joint the pain is usually too insignificant to attract the patient's continued attention or cause him to seek medical advice. In a fracture, on the other hand, the pain is, in most cases, sufficiently severe to lead the patient to suspect a severe injury, and he is therefore likely to demand immediate medical attention.

In sprain one almost always finds that the initial pain is associated with a greater or less degree of modification of the function of the involved joint, this change being due to the distress caused by attempts to use it. In a small proportion of the cases the patient is surprised to find that passive movements of the joint are not painful immediately after the receipt of the injury.

Pressure upon the joint elicits pain. The tenderness is more apparent at certain injured points than at others, and manipulation of the joint is accompanied by pain which is general and special at the seat of greatest injury.

Swelling of the parts covering the superficial joints is almost always manifest, but deep-seated joints, such as the shoulder and hip, may never show any appreciable puffiness. The amount of swelling may be taken as an index of the severity of the sprain.

Ecchymoses of greater or less extent indicate that blood-vessels have been lacerated. As a rule, a day or two will elapse before the blood makes its appearance, the length of time depending on the depth of the seat of injury and the direction of the muscular planes. The hemorrhagic discoloration should lead one to a more careful search for a fracture, especially when this disfigurement is at some distance from the seat of injury.

The rapidity with which the symptoms develop varies with the severity of the original injury, and is influenced to a very considerable extent by the method of treatment employed. The natural course of the disturbance is that of increasing swelling and diminishing usefulness of the joint for one or two days. The patient usually complains of more pain and stiffness the day after the injury, and sometimes the disability remains for an indefinite period; but, as a rule, the swelling begins to subside, the pain to diminish, and the functional power to improve in the course of two or three days, and, by the end of a week, the joint is capable of resuming its full function. In some cases the joint remains impaired for a much longer period; and in a few the injury seems to be followed by a more or less permanent disability.

Diagnosis.—The history of the case, combined with the usual symptoms of pain, tenderness, swelling, and impaired function, will, as a rule, be sufficient to make the diagnosis clear. If, however, any doubt exists, an *x*-ray examination should be made, if practicable. Indeed, this may be done as a regular procedure in all cases of injury to a joint. A negative radiogram is the best possible confirmation of a correct diagnosis.

A study of cases of supposed sprains by means of the Roentgen ray demonstrates the fact that fractures of the bones are much more common than they were formerly thought to be. It is wise, therefore, to subject cases of sprains to an examination with the *x*-ray in order to exclude fractures. A recent case of "sprain" of the wrist revealed, in a skiagram, a fracture of the lower end of the radius without any displacement whatever. Because of the absence of

the cardinal symptoms of fracture the case passed through the hands of several physicians, each of whom diagnosed a sprain.

Complications.—As a rule, complications, other than an occasional slow return of the normal function, do not occur. The joint may remain tender and abnormally sensitive to injuries for a long time. Pain before and during rainy weather may persist for years. If the joint should remain permanently enlarged, the persistence of such enlargement is suggestive of an overlooked fracture or of an unusually severe injury. A gouty or rheumatic diathesis may be instrumental in producing a permanent enlargement and prolonged incapacity.

Observation seems to have demonstrated the probable association between apparently trivial injuries to joints and the subsequent development of tuberculous lesions in the injured articulations. (See Vol. II, p. 75.) It is probable that this occurs only in those who already are predisposed to tuberculous manifestations, because sprains are such common accidents that, were there any direct relationship, joint tuberculosis would be far more frequent than it is at the present time. The most probable explanation of this seeming association is that the sprain or injury causes an effusion into a joint, and that the slowing of the circulation, coincident with the reparative inflammation, offers a favorable opportunity for the tubercle bacilli to locate and thrive. Once established, the organisms are given every chance to assume the offensive against the tissues of the joint, particularly the synovial membrane, which is probably, in a majority of cases, the first structure affected. The rôle of trauma in joint tuberculosis receives much support from the well-known fact that injuries to joints which were once the seat of the disease, but in which the process had become quiescent, are very likely to produce a recrudescence of the disease. Injury seems to exercise an influence in causing tuberculosis to locate in a joint which otherwise would entirely escape the disease.

Sequelæ.—Ankylosis, true or false, may follow a sprain. This is particularly true when the injury is severe and when prolonged rest of the joint is prescribed as a part of the treatment. Fibrous ankylosis, of greater or less degree, is not at all uncommon in the cases in which there has been marked synovitis following the injury. Children not infrequently exhibit a fear of movement of the joint, and this fear may persist so long as to give rise to more or less ankylosis and also to contraction of the muscles which move the articulation.

There may be, on the part of the synovial membrane, an inflammatory action which will lead to such an increase of synovial fluid as to cause distention of the joint. This serous fluid may be absorbed and a dry synovitis follow, or the effusion may persist and a chronic hydrops articuli result.

There is a very annoying class of cases in which, after a comparatively simple injury, marked and progressive stiffness of the joint occurs. Although

many of these cases are those in which too prolonged immobilization has been practised, there are some in which this unfortunate development occurs quite independently of any treatment directed to the fixation of the joint. Some authors have ascribed this tendency to a gouty or rheumatic diathesis, and people with such a tendency are undoubtedly more prone to an articular inflammation which may tend to impair the mobility of the joint; but one meets with an occasional case in which no such tendency is demonstrable, and yet a strong predisposition to fibrous ankylosis is apparent. The accompanying inflammation is of a low grade, and adhesions are apt to form, or the trouble may seem to be located in the muscles or tendons which move the articulation.

Such cases may require, upon repeated occasions, the employment of a general anæsthetic for the purpose of subjecting the ankylosed joint to forced movements. As a rule, the persistent employment of such movements, of massage, and of applications of hot air will result in useful, movable joints. Fixation will almost certainly lead to permanent loss of function in these cases.

General Principles of Treatment.—The special methods of treatment will best be dealt with when the wounds of individual joints are considered, but there are certain underlying principles which are applicable to all cases of sprains.

Heat or Cold.—The application of warmth, dry or moist, is almost always grateful to the patient and seems to "take the soreness out" better than cold does. Some persons derive more comfort from an ice cap than they do from heat, but the rule is that applications as hot as can be borne are to be preferred.

In order to obtain the good effects of either heat or cold these agents must be applied in such a manner as to produce the most pronounced effect upon the injured part. They are used with the twofold idea of checking effusion or hemorrhage, or both, and of preventing an undue inflammatory reaction. When heat is used, the injured joint should be immersed in water at as high a temperature as can well be borne, and kept there for a considerable time, additional hot water being added at intervals to insure the maintenance of a sufficiently high temperature. The use of a thermometer in the water will enable one accurately to maintain the desired temperature. When the sprained part is removed from the hot bath it should be bandaged, preferably with a flannel bandage, to put the parts at rest and to cause an even elastic pressure upon the joint. This method affords the patient great comfort and at the same time prevents undue effusion. An elastic bandage answers the same purpose in even a more satisfactory manner.

Cold is most conveniently applied by means of an ice cap. The best results are obtained by applying a bandage and then surrounding the joint with ice caps which nowhere come in contact with the skin. Damage may be done the soft parts by permitting ice caps to come in direct contact with the skin; sloughing, for example, of the turgid, swollen, or otherwise devitalized tissues

may follow, and serious complications may be caused. In the absence of ice caps, continuous cold may be obtained by using cold water by means of cloths or, better still, by its continuous discharge through a rubber tube coiled around the joint. To intensify the cold, cracked ice may be added to the water.

The sprained joint should be elevated whenever possible.

Massage.—The natural impulse of an individual is to stroke or rub the injured joint, and this inclination gives us a hint as to the value of massage. This remedy has been found to be of the greatest value when applied to the more superficial joints—those which may most easily be thus treated. The deeper joints are also benefited by massage, but not to the same degree as those which are more readily accessible to the treatment. Massage must be regarded as possessing much virtue in the treatment of this disorder. It should be applied first to the muscles in the neighborhood of the joint, and later to the injured articulation itself. It is of material assistance in removing the effusion from a joint and the exudation from the overlying and contiguous tissues.

Fixation or Immobilization.—This method of treatment is indicated in the class of cases in which abnormal mobility of the joint is present, because undue movements are indicative of rupture or stretching of the ligaments or tendons. The proper healing of these structures is favored by immobilization. In the cases in which abnormal movements are not present, fixation may do much harm by inducing a stiffness (ankylosis) of the joint which may persist for an indefinite time. Hence fixation should be employed only in those cases in which special indications for its use are apparent. As a general rule, early movement is preferable to prolonged immobilization.

Active and Passive Movements.—The best rule in slight cases is to apply the dressings in such a manner as to permit of the normal range of movement, but at the same time to prevent the possibility of abnormal or extreme movement. In the knee, for instance, when advisable, apply lateral splints to prevent lateral movement of the joint, and yet they should not be applied in such a manner as to interfere with the normal flexion and extension. In severe injuries passive movements should be instituted early in order to prevent adhesions from forming. Active movements should be begun just so soon as the swelling and pain will permit of this use of the joint. It is probable that in many instances active movements are interdicted for too long a period, and that partially disabled joints result from this too conservative plan.

Pressure.—This is of more value than any other single method of treatment for sprains, but its efficiency depends upon the thoroughness with which the indications are met. In order to secure pressure upon the proper parts by bandages, great care must be taken to avoid exerting pressure upon the bony prominences, to the exclusion of the joint itself. In order to prevent effusion, the bandage must be so applied as to fit snugly to the circumarticular region. This is best accomplished by surrounding the parts with cotton or

other elastic substances and then applying, over all, the bandage firmly and smoothly. A properly fitting bandage will, not infrequently, prove of great benefit in twenty-four hours. Its use following the application of heat or cold may seemingly produce marvellous results within a short space of time. The elastic-webbed bandage possesses advantages over those composed of other materials because with it one may be assured of continuous, even pressure. Great caution, however, should be exercised in its application, otherwise a too severe pressure may be made, as the elastic bandage, especially, is continuously operative.

Counter-irritants.—Tincture of iodine has long held a high place in the esteem of physicians for the treatment of sprained joints, particularly in those cases which recover slowly. It is commonly applied quite widely over the area of the joint, and its use is repeated each day until the tissues begin to show signs of superficial irritation. This remedy does seem in some cases to hurry along the absorption of the effusion and thus aids in the restoration of the joint. In any event, however, the charm of its action in other respects often exercises a healthful influence on the mind of the patient—a desideratum not always to be neglected. Compound iodine ointment faithfully applied is a better therapeutic agent in many respects than is the tincture of iodine.

Blisters over the joint are of value in the cases which progress slowly and are accompanied by persistent, localized pain. The blister should, if possible, be applied over the painful spot. In some peculiarly persistent cases a ring of blistering may be made to encircle the joint. Vesication should not be resorted to in cases in which subsequent operative procedures are contemplated, because of the danger of infection from the blistered surface.

Flicking of the skin over an injured joint with the white-hot point of the thermo-cautery has been advised and practised. The point simply touches the skin in a glancing manner, the contact being for so short a time as to insure against a burn of any moment. The moral effect of this application is usually good; hence it is of particular value in those cases in which there may be a lurking suspicion of hysteria. It does, however, have a positive value in relieving pain.

Ichthyol, oil of eucalyptus, oil of wintergreen, and other volatile substances have obtained more or less favor in the treatment of these joint affections. They are of doubtful utility in traumatic cases.

Liniments.—Two or three decades ago much of the treatment of sprains consisted in the use of some variety of liniment. The main value of these preparations probably consists in the thorough rubbing administered to the parts, and to this extent, like those mentioned in the preceding paragraph, they are useful as adjuncts in the treatment of these affections.

The researches of Hilton seem to lend some color to the belief in the possibility of affecting the deeper parts through the medium of the superficial nerve

supply. It might be well, before discarding counter-irritants, to make a thorough, scientific investigation of their reputed value.

Incision, removal of blood, and drainage of the joint have been recommended by O'Conor in the treatment of large and persistent bloody effusions.*

His reason for this active intervention is "that the liquid portion probably may be absorbed, but we also know that clots favor the formation of adhesions and possibly movable bodies, and thus the future utility of the limb runs a risk of being permanently impaired." The advantages afforded by an incision are believed by him to be these: The incision affords an opportunity of removing thoroughly all blood and clots; it opens the way for a digital examination; it renders possible the arrest of hemorrhage by packing the joint cavity with gauze; it affords rest to the injured synovial membrane by establishing good and continuing drainage; and, finally, it gives the overstretched ligaments an opportunity of promptly and permanently contracting to their normal state. O'Conor also advises that, in every simple case of traumatic synovitis in which there is an excessive quantity of fluid exudation, the joint should be opened whenever, after the lapse of three weeks of expectant treatment, there is no evidence that this mass of fluid is undergoing spontaneous absorption. He believes that, by the adoption of this plan of procedure, permanent thickening of the synovial membrane will often be prevented and the patients themselves saved from the misfortune of having a weak knee for the rest of their lives.

This treatment seems somewhat heroic, but is often justifiable if aseptic precautions can be carefully carried out. The blood and synovial fluid in the joint afford such good culture media that the success of the operation is probable only in the hands of one who is efficient in aseptic technique. Infection of this joint is a more serious matter than the results of non-interference. This method of treatment, though rational and safe under proper circumstances, must be resorted to with great caution under ordinary conditions.

Treatment of Hysterical Joints.—In order successfully to treat cases of this sort it is absolutely essential that they be isolated from sympathizing, solicitous relatives and friends. The patient may be taken to a hospital and subjected to the full régime embraced in the "rest cure" so admirably described by Weir Mitchell. The full course of treatment is advisable in this instance because the existence of this peculiar joint trouble should be taken to indicate a general mental condition which also requires treatment.

When the condition is one of pure simulation the detection of the sham usually leads to a rapid, if not instantaneous, disappearance of symptoms. Should the patient persist in the pretence, the physician will do well to consider again each detail of the case, so as to be certain that he is not mistaken in his opinion. An anæsthetic should be given and pushed to the point

*John O'Conor, M.D.: Annals of Surgery, vol. xxiv., p. 620.

of complete muscular relaxation; and if, with the muscles thus relaxed, the joint movements prove to be free and unhampered, he can then feel certain that his judgment is correct. He may receive further confirmation of his opinion by noting the fact that the rigidity begins to return only after the patient has regained consciousness sufficiently to be capable of designing acts. An inflamed joint begins to become rigid so soon as the patient is sufficiently conscious to experience pain.

Having arrived at a certain diagnosis one can usually persuade the patient to abandon the deception, unless his seeming infirmity is the principal asset in his business of begging or defrauding the public.

WOUNDS OF INDIVIDUAL JOINTS.

The joints most frequently sprained are the ankle, the wrist, the knee, the back, the hip, the shoulder, the elbow, and the fingers. We will consider them, however, in their natural order, from above downward.

The Back and the Neck.

Sprains and Contusions of the Back and the Neck.

The complicated construction of the spinal column leads one to believe that the joints of this osseous pillar may be the recipients of trauma sufficiently often to render sprains and contusions quite common, but experience seems to prove that these joints are but seldom the seat of injuries such as we are considering. It is perhaps a general custom for physicians to place too much stress upon the presence of symptoms indicative of injury to the spinal cord. One is prone to regard the cases in which there are no nervous symptoms as being trivial in their nature and not serious as to prognosis. There is, however, a large class of patients who present persistent and distressing symptoms after injuries to the back and neck, and the only plausible explanation is that either the spinal articulations have been injured, or that the muscular layers of the back have been so involved as to render them incapable of performing their functions for a considerable period of time. It seems highly probable that the muscles are at fault in a majority of these cases, but there can be no doubt but that the joints of the spine are occasionally involved. The application of great force to this region will, as elsewhere, produce a fracture or dislocation; but a lesser force may produce a sprain or contusion.

The fact that the cervical and lumbar portions of the spinal column are unsupported by adjoining bones renders them more subject to sprains and contusions.

Treatment.—Rest, during the acute stage, may be associated with fixation by means of bands of adhesive plaster. When the more acute symptoms begin to subside, massage and active movements are indicated.

Prognosis.—Such cases usually terminate in an early and complete recovery, but a few will improve slowly, or a chronic disability may result. The so-called "railway spine" is an example which is familiar to most surgeons.

Wounds of the joints of the back and neck are unusual, except those due to bullets; and in these cases the spinal cord and its membranes are likely to be injured. (See the article on "Gunshot Wounds" in Vol. II.)

The Shoulder.

Sprains and Contusions of the Shoulder Joint.

Sprains and contusions of this joint usually occasion but transient disability. Because of the deep situation of the joint and the ample protection afforded by the large muscular masses surrounding it the major part of the effects of contusions is experienced by the overlying structures. Sprains are unusual because of the very free range of movement normally present. When they do occur they are generally the result of a force which tends to drag the head of the humerus away from the glenoid fossa, and thus put the ligaments upon the stretch. This violent dragging upon the upper extremity does sometimes take place when the hand or arm is caught in moving machinery or in other accidents in which the weight of the body is opposed to a force tending to drag the arm away from the body. It is highly probable that the majority of these cases are to be regarded as momentary, incomplete dislocations.

Symptoms.—It will sometimes happen that severe contusions of the shoulder are followed by symptoms referable to bruising or tearing of some of the nerves in the vicinity of the articulation. The circumflex nerve, in particular, may be temporarily or even permanently injured and incapacitated. The resulting disability is sometimes wrongfully attributed to intra-articular conditions.

As the most marked symptom of injury to the circumflex nerve may be mentioned a deltoid paralysis; patients who are thus affected are unable to lift the arm from the side. In the course of time atrophy of the deltoid appears. The resulting picture is not infrequently mistaken, at first glance, for a dislocation.

Diagnosis.—The diagnosis of a sprain or contusion must be based largely upon the history of the case, the painful movements, and the greater or less disability of the joint. Examination with the *x*-ray will prevent many errors of diagnosis.

Treatment and Prognosis.—The treatment does not differ in any essential particular from that given above.

The prognosis is usually good. The joint resumes its normal function within a reasonable time. The outlook is not so favorable when there is injury to some nerve trunk. Statistics seem to indicate that a permanent paralysis remains in about sixty per cent of the cases.

Penetrating Wounds of the Shoulder Joint.

Wounds of the shoulder joint include gunshot, incised, punctured, machinery, and railroad traumatisms.

In gunshot wounds the greater part of the injury is inflicted upon the bony structures, particularly upon the head of the humerus. Fissures or fractures may extend from the extra-articular structures into the joint. The joint cavity may be opened by the bullet or by osseous fragments. Coincident injury to important vessels or nerves may occur and add greatly to the seriousness of the outlook.

Diagnosis.—The diagnosis is quite easy when the track of the bullet leads directly into the joint, but, when the involvement of the joint is secondary to a primary injury of the adjacent parts, one may be in doubt as to the existence of an intra-articular involvement, because there may be no escape of synovial fluid in appreciable quantity.

Complications.—The complications are those which arise from injury to the adjacent parts. The structures in the axilla are sometimes injured, and these injuries often overshadow the articular injury.

Treatment.—The immediate proper care of the wound is of great importance. The course of these cases is largely influenced by the immediate resort to proper aseptic measures. It is best to avoid every possible manipulation (probing, etc.) which may lead to the carrying of infection into the wound. The wounds of entrance and exit should be covered with aseptic or antiseptic gauze until it is possible to clean and sterilize the surrounding parts (the proper method of doing this has been described elsewhere in this article). In the absence of active symptoms the wounds should be left alone, and healing will then, in many cases, proceed smoothly and rapidly.

When infection occurs it will be necessary to open the joint freely and provide for free drainage. Loose fragments of bone must be removed. In some cases excision of bone to a greater or less degree is urgently demanded. Formal excision may be necessary, but it is advisable to confine one's interference to the removal of those bony parts which must necessarily perish. In other respects treat the injury according to the general rules laid down for the treatment of wounds of joints. Primary amputation for gunshot or other wounds of the shoulder joint is never advisable unless the injury to the main blood-vessels is such as to render gangrene of the member inevitable. Secondary amputation may become necessary in patients in whom an unusually severe

degree of infection develops. With the increasing care which is exercised at the present time in the early treatment of wounds it is probable that amputation will be resorted to but seldom.

Any other wound—punctured or incised—which penetrates the joint must also be regarded as a serious injury,—one that requires prompt and intelligent treatment. Early treatment may prevent infection and thus reduce the dangers to a minimum. Should infection occur, one must, by following well-known rules, seek to limit its baneful effects. Free incision and good drainage accomplish much in limiting the amount of destruction.

The Elbow Joint.

Sprains of the Elbow Joint.

Sprains may affect either the elbow joint proper (articulation of ulna and humerus), or the radio-humeral joint alone may be involved. When the ulno-humeral joint is affected, which occurs but rarely, the pain is produced by the movements of flexion and extension. Pain upon pronation and supination calls attention to the radio-humeral junction and the upper radio-ulnar articulation. These injuries are usually produced by an over-energetic use of the arm in the direction of its normal movement. Excessive pronation or supination, particularly if accomplished by a quick movement, may lead to sudden disability, with the subsequent manifestations of a sprain. As a rule, the effusion is not marked in the region of the radio-humeral joint. When the humero-ulnar joint is affected the effusion is located upon either side of the olecranon. The joint is held in a flexed position when effusion is present, because the capacity of the joint is greater in that position. Involuntary contraction of the biceps is a very early symptom of inflammation of the elbow joint.

The symptoms are those referred to above in connection with other joints. The diagnosis is made by the combination of symptoms characteristic of this condition.

The prognosis is good, as a rule.

The treatment is the same as that previously outlined, except as modified to suit this particular joint.

Penetrating Wounds of the Elbow Joint.

Wounds are more often of the lacerated than of the incised variety. Treatment must vary according to whether amputation is imperative or not. Partial or complete excision of the joint may be advisable when the injury to the soft parts is not extensive, and the bony parts are not involved except in the immediate vicinity of the articulation. The question between amputation and excision must be decided according to the general principles which govern the

performance of these operations. (See articles on "Amputations" and "Excisions" in Vol. IV.)

When it is possible to save the member, place the limb in a right-angled position so that the greatest range of usefulness may be obtained in case ankylosis occurs.

Acute suppurative arthritis is to be treated by free incisions on either side of the olecranon. Free drainage must be provided and all burrowing of pus must be followed up by incisions and drainage.

The Wrist.

Sprains of the Wrist.

Sprains of the wrist are most commonly produced by falls upon the outstretched hand, producing hyperextension; or the hand may be "doubled under" and a sprain result from forced flexion. Instead of a rupture or overstretching of the ligaments taking place, a Colles' fracture may result. Forced pronation or supination and too great radial or ulnar adduction may produce sprains of the wrist joint and of contiguous tendons. Exaggerated rotary movements are more likely to cause trouble in the radio-humeral articulation, but they may affect the radio-carpal joint.

When the sprain is produced by hyperextension, evidence of the fact that the flexor tendons have been injured will usually be afforded by the pain caused by flexing the fingers, and also by the effusion which is present in the tendon sheaths. Tearing of the transverse ligament to a greater or less extent usually accompanies a sprain from hyperextension.

Symptoms.—Many of the symptoms and much of the disability in sprains of the wrist are due to the involvement of structures which are entirely extra-articular—such, for example, as the tendons or tendon sheaths. In many of the cases pain upon movement is dependent upon injury to the tendon sheaths, followed by an inflammatory process which interferes with the free movements of the tendons. One can frequently feel that the tendons and their sheaths seem to be enveloped by an effusion which surrounds them in such a manner as to suggest their having been embedded in a mass of inflammatory material that has "set." The decrease of the primary swelling renders the condition of the parts more apparent. This condition often proves most refractory to treatment, and fixation intensifies the tendency to permanent lack of mobility. Movements dependent upon the action of these tendons may become more and more restricted, and in some cases a stiff, useless hand may result.

Treatment.—Here, as in other parts of the body, the treatment should vary with the degree of the injury and the condition of the parts. In the milder cases the application of heat or cold, followed by snug bandaging, and this in turn being supplanted by massage and active and passive movements, may

constitute the only necessary treatment. A large amount and wide distribution of effusion call for early massage, but the manipulations should be very gentle and of such a nature as to assist in the absorption of the effused material. Passive movements of the fingers should be begun as early as the third day and should be persisted in most faithfully. When the fingers show an increasing stiffness, forcible movements under an anæsthetic may be resorted to, the subsequent tendency to inflammatory reaction being controlled by the use of ice caps.

Blisters and other counter-irritants may be of value in the treatment of these cases when absorption is delayed and the parts recover their function very slowly. Baking the parts in a hot-air apparatus is frequently of value in the treatment of old sprains. Temporary packing in flannel saturated with hot water is likewise efficient.

Prognosis.—The rule is that these joints recover promptly and remain well, but there may be cases in which recovery is very slow. Occasionally, fortunately very rarely, the injury is followed by prolonged pain and tenderness, loss of function, and prolonged, even permanent, serious disability of the joint, especially in advanced life, with rheumatic complications.

Sequelæ.—Because of the complicated structure of the joint, a serious sprain of the wrist is more likely to be followed by long-standing disability than is a fracture of one of the long bones. In sprains of the wrist the evil effects may fall more or less equally upon the tissues composing the joint, or one structure may suffer out of proportion to the others. The sequelæ of injuries to the wrist may affect the joint itself or they may manifest themselves in the tendons, or even in the muscles which are responsible for the movements of the joint.

Long-continued pain may remain after the objective signs of injury have entirely disappeared. When the pain is not dependent upon motion, the condition has been called "neuralgia," for the reason that no clear conception of its cause is available. When the pain is provoked by movement it is probably caused by bands or adhesions in the joint or by chronically inflamed tendon sheaths. Crackling of the joint upon movement may be due to a chronic dry synovitis or to an involved tendon sheath.

Painful or limited pronation and supination may be due to an overlooked injury to the upper radio-ulnar articulation, with a displacement of the articular disc of cartilage. These results are likely to be permanent.

Lacerations of Ligaments of the Wrist.

The symptoms of primary laceration or rupture of the ligaments of the wrist are similar to those described in connection with a like injury to the ankle joint. The proximity of the carpal articulations renders it diffi-

cult to decide whether the damage has occurred in the wrist joint or whether the brunt of the injury has fallen upon the smaller joints. In view of the fact that the treatment of the two conditions is practically the same it is not a matter of much importance to make a very clear differential diagnosis.

Symptoms.—The symptoms are those which result from the impairment of function, in addition to the pain, tenderness, swelling, extravasation, etc., noted in the description of similar injuries to the ankle joint. (Page 755.)

Treatment.—The early treatment by hot or cold applications, massage, passive movements, etc., should follow the general plan outlined above.

Secondary lacerations in connection with Colles' fracture are quite common and they frequently coexist with severe strains of the tendons in the proximity of the joint. One must constantly bear in mind that the fracture is of secondary importance so far as the future value of the joint is concerned. Hence, while treating the fracture, one should devote much attention to the proper care of the tendons and ligaments. The early use of massage and passive movements, and the early discarding of fixation, will frequently bring about a complete restoration of function by the time the bone has knit firmly. Prolonged fixation of the wrist in the treatment of a Colles' fracture is not an advisable procedure.

Crushes of the Wrist.

Crushes of the wrist are quite common as the result of injuries from machinery, but it is very unusual to have the wrist joint involved without also having severe injuries to the surrounding parts. It follows, therefore, that these injuries call for treatment along general surgical lines, the question usually being whether it is best to amputate or whether an attempt shall be made to save the injured member. In the former case the general rule, that an amputation shall be made at the lowest possible point consistent with the obtaining of good flaps, holds good. The variety of amputation will depend upon the nature of the injury to the skin; flaps should be taken in such a manner as to sacrifice a minimum of viable tissue.

If the surgeon decides in favor of a more conservative plan of treatment the parts should be very thoroughly cleansed, all badly torn or loosened ends of tissue should be cut off, and all foreign substances should be carefully sought for and removed. After the parts have been rendered as nearly surgically clean as possible, the surgeon, with sterile finger, or better, with the hand covered by a sterile rubber glove, should thoroughly explore the interior of the wound in order to ascertain the extent of the damage to the tissues. Incisions for drainage should be made into all blind pockets, and tags of tissues which are likely to die should be removed, because this procedure will materially reduce the amount of tissue to be gotten rid of by suppuration, and will thus considerably shorten the period of repair. Careful trimming of the tissues may assist not

a little in preventing a secondary amputation. The exploring finger should make careful note of the condition of the fractured bones, and their replacement should be brought about by manipulation in association with the other hand on the outside.

Irrigation of the wound is advisable when there is gross contamination, but, when such does not exist, dry sponging carried out in a systematic manner is preferable. When irrigation is employed, its cleansing effects should be aided by the use of gauze sponging of the interior of the wound. No part of the wound should be overlooked or neglected in this cleansing.

The advisability of using sutures will depend upon the nature of the wound in the skin. When very extensive laceration exists, a few sutures should be used to hold the flaps loosely in place, but tension of the tissues must be scrupulously avoided. When there is extensive laceration of the deeper parts, with only a small opening in the skin, it is better in most cases to enlarge the opening in order to permit the free escape of fluids.

The next step in the proper management of the case is to place drains in such a fashion as to insure the perfect escape of all fluids that may develop. All gauze drains should be moistened before being placed in position, because dry gauze is not nearly so effective a drain as is moist.

The bony parts must now be approximated and maintained in their normal relations while an abundant aseptic dressing is applied. The limb is then to be bandaged to a suitable splint—one that will assist in retaining the parts in their proper relations.

Should the secretions from the wound soak through the dressings, new dressings should be applied, but, in the absence of such saturation, twenty-four or thirty-six hours may be permitted to elapse before the parts are re-dressed. At the end of forty-eight hours the more superficial drains may be removed; the remaining ones should be removed when they no longer serve any useful function. The drains are foreign bodies and interfere with healing when allowed to remain after they have served their purpose. Healing is not infrequently delayed by the too prolonged use of drains.

It will be necessary to use an anæsthetic in order properly to prepare and cleanse wounds of this nature; it is well, therefore, to administer the anæsthetic before any attempt is made to examine the limb.

If, during the course of treatment, untoward symptoms—fever, rigors, or severe pain—arise, the wound must be carefully examined for pus pockets or other complications. Widespread, general involvement of the tissues will make an amputation advisable, but localized infection will call for more incisions and drainage.

It is very important to remember that the position given the limb in the primary dressing will probably be the one the limb will assume after healing is complete; hence one must be very careful to see that the joint is so fixed as to

give the limb the greatest usefulness, because it is very nearly a foregone conclusion that ankylosis of the joint will occur and be permanent.

It is a matter of common observation that wounds of parts thoroughly soaked with the oils used about machinery do very well, the oil seeming to exercise a beneficent influence upon the course of repair.

Incised and Punctured Wounds of the Wrist Joint.

Incised and punctured wounds of the wrist joint are very uncommon. When they do occur they should be treated in accordance with the general principles already outlined. The possibility of one or more tendons being cut should always be borne in mind. When such division has taken place immediate suture of the ends should be practised according to the methods described under the heading of "Suturing of Tendons." (See p. 411, Vol. II.)

THE HAND.

Sprains of Fingers.

Sprains of individual fingers, particularly of the thumb, are quite common. In many cases the brunt of the injury falls upon the tendons, and the active symptoms are dependent upon their involvement. Care must be taken to eliminate the possibility of a fracture or dislocation. Some cases of sprains are followed by permanent contraction and disability of one or more tendons.

The treatment should follow along the lines mentioned above, but especial care must be taken to institute early and persistent movement of the member.

Penetrating Wounds of the Joints of the Hand.

Wounds of the joints of the hand are quite common and are often fraught with dire consequences. Infection is to be most carefully guarded against, because when the tissues of the hand become the seat of suppuration the condition is always serious and sometimes fatal. A crippled, useless hand and wrist are not infrequent sequelæ of suppuration in and about the carpal and metacarpal joints. The involvement of the tissues of the palm has already been considered in the preceding volume (Vol. II., p. 428 *et seq.*); but, in view of the fact that this is a very formidable condition, and also because it most frequently originates from a wound and infection of one or more of the joints of the hand, it should receive some attention in this connection.

Punctured wounds are particularly apt to give rise to serious mischief; even punctures with sewing needles are sometimes followed by a train of symptoms and conditions which will tax one's surgical ability to the utmost. The one

great difficulty in the management of these cases is due to the negligence of those upon whom such wounds have been inflicted. They are prone to regard such injuries as trivial (as a rule, bad consequences do not follow), and go on with their work without taking any precautions to prevent the slight wound from becoming infected. The infecting material is sometimes carried in with the puncturing body, but in not a few cases a later infection occurs.

Treatment.—The prophylactic treatment is very important. All wounds of the joints of the hand should be protected against the possibility of infection by careful cleansing and the application of aseptic dressings. This method will prevent trouble in all cases except those in which infection occurred at the time the wound was inflicted. So soon as evidences of infection of the joint make their appearance the latter should be opened by a free incision—one through which the joint can be drained freely and completely. This early free incision is the sovereign remedy in the condition under consideration. Temporizing measures are more than useless, as is evidenced by the many disabled, crippled hands which have resulted from expectant treatment. Incise early and open the joint thoroughly. It is not advisable to await the appearance of fluctuation, because fluctuation is not obtained until after the fluid has penetrated the capsule of the joint and has accumulated in the tissues outside. The use of hot, moist antiseptic dressings after incision is grateful to the patient and advisable from every standpoint.

In view of the fact that these fingers are, as a rule, exceedingly painful, and that the use of the knife causes agony, it is always advisable to employ a local anæsthetic. Cocoain injections are not efficient, because the increased tension caused by the injected fluid is unbearable. Ethyl chloride sprayed upon the part usually acts nicely, but if it be found inefficient one need never hesitate to employ a general anæsthetic. Nitrous oxide finds one of its greatest fields of usefulness in just such cases.

The above-described mode of treatment is almost invariably successful when the case is seen before the infection has spread from its original focus to the surrounding parts, but, when the barriers to its progress have been broken through, a successful outcome to the case depends upon the free opening of all pus pockets and free drainage of the same. Kanavel* has shown, by carefully conducted experiments, that there are "five great spaces, with their tributaries, in which pus may accumulate (Figs. 303 and 304):

"First, the dorsal subcutaneous, an extensive area of loose tissue, without definite boundaries, which allows pus to spread over the entire dorsum of the hand.

"Second, the dorsal subaponeurotic, limited upon its subcutaneous side by the dense tendinous aponeurosis of the extensor tendons, upon the deep side by the metacarpal bones, having the shape of a truncated cone, with the

* Surgery, Gynæcology, and Obstetrics, September, 1905.

smaller end at the wrist and the broader at the knuckle. Laterally, the aponeurotic sheet shades off into the subcutaneous tissue.

"Third, the hypothenar area, a distinctly localized space.

"Fourth, the thenar space, occupying, approximately, the area of the thenar eminence, to the flexion adduction crease of the thumb, not going to the ulnar side of the middle metacarpal. It should be remembered that this space lies deep in the palm, just above the adductor transversus.

"Fifth, the middle palmar space, with its three diverticula below along the lumbrical muscles, limited by the middle metacarpal bone upon the radial side, overlapped by the ulnar bursa upon the ulnar side, and separated from the thenar space by a partition which is very firm everywhere except at the proximal end, where it is rather thin. A small isthmus can be found leading from the proximal end of the space under the tendons and ulnar bursa at the wrist up into the forearm."

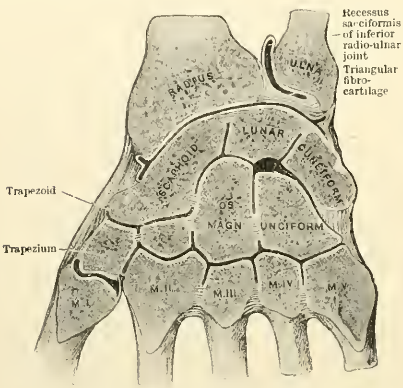

Fig. 303.—Coronal Section (diagrammatic) through the Radio-carpal, Carpal, Carpo-metacarpal, and Intermetacarpal Joints, to Show Joint Cavities and Interosseous Ligaments. (From Cunningham's "Textbook of Anatomy.")

Infections of the joints of the middle and ring fingers, and of the radial side of the little finger, are capable of conveying contamination to the middle palmar space.

The thenar space might receive infection from the index finger and the ulnar side of the thumb.

Suppurative arthritis of the distal joint of the thumb may give rise to involvement of the hypothenar space.

Infections of the middle and ring fingers may lead to involvement of the dorsal subaponeurotic space.

Involvement of the dorsal subcutaneous space is possible in any infection of the fingers or thumb.

From the anatomical details mentioned above it naturally follows, according to Kanavel, that, if the middle palmar space is to be opened, an incision should be made in the skin over the metacarpal space between the middle and ring fingers, just where the middle palmar crease crosses said space. The incision may safely be made through the palmar aponeurosis, but the subjacent tissues should be perforated with an artery forceps the point of which should be forced through to the dorsum of the hand. Through-and-through drainage

is always indicated, according to Kanavel, but it is highly probable that he is unnecessarily radical in this recommendation.

The thenar space is best opened by an incision made on the radial side of the index metacarpal.

Incisions in the metacarpal spaces will most efficiently drain the dorsal subaponeurotic space, and at the same time all danger of injuring the tendons will be avoided.

Should the pus pass under the annular ligament and appear in the forearm, the accumulations must be evacuated wherever found. In some cases the infection becomes so widespread and advances so rapidly that amputation becomes the conservative method of treatment.

Fig. 304.—System of Bursæ of the Palmar Aspect of the Wrist, Hand, and Fingers. (From Gray's "Anatomy," Lea Bros. & Co., Phila.)

Prognosis.—When the disease remains confined to one or more joints of the fingers or hand there is no serious threatening of life, but the infected joints become stiff, the ankylosis, as a rule, being permanent and irremediable. Because of the inconvenience and uselessness of these stiff fingers patients will frequently insist upon having them removed—the hand being more useful after their amputation.

The Hip.

Sprains and Contusions of the Hip Joint.

The protected position of the hip joint renders contusion of its structures very improbable, even though great force be expended upon the tissues overlying it. The traumatism will be inflicted ordinarily upon the surrounding parts; hence, one is much more frequently called upon to treat contusions of the muscles in the neighborhood than to care for actual contusions of the joint. Falls upon the knee or upon the great trochanter may produce a traumatism of the hip joint by the transmission of the force to the upper end of the femur.

Etiology.—Sprains of the hip are produced, like sprains of other joints, by movements which exceed the normal range. The very free range of movement permissible in the hip makes sprains or lacerations of the ligaments un-

usual happenings. The muscular fibres of the thigh are much more likely to suffer than are the integral parts of the joint. Injuries of the hip joint in children must be regarded as being of serious import because a disability may subsequently develop from what appeared at the time of the occurrence to be a simple sprain or contusion.

Diagnosis.—The diagnosis is made by excluding other, more serious injuries. The methods of diagnosis referred to above will serve to establish the nature of the injury. Swelling, the result of serous or hemorrhagic effusion, is seldom sufficient to be apparent.

Treatment.—The treatment should follow the lines detailed above.

Prognosis.—The outcome is generally very satisfactory, but, especially in children, a chronic (tuberculous) condition may follow in the wake of an apparently trivial injury. One should therefore give a guarded prognosis.

Penetrating Wounds of the Hip Joint.

Penetrating wounds of the hip joint are most frequently the result of gunshot injuries, although incised or punctured wounds may possibly occur.

The treatment will be the prevention of infection. If there be any loose bone, it will be necessary to remove it, or a suppurative synovitis may supervene. These conditions must be treated according to the general rules already laid down elsewhere in this work. (See article on "Gunshot Wounds" in Vol. II.)

The Knee.

Contusions and Sprains of the Knee.

Etiology.—Sprains of the knee joint are most frequently caused by forced lateral movement, although similar conditions may be produced by excessive flexion or extension. Force applied so as to produce a twisting movement at the knee joint may also be responsible for sprains.

Pathology and Symptomatology.—The pathology of the affection is similar to that considered in detail in the early part of this article. The symptoms are those given under the symptomatology of sprains of the other joints.

The knee joint is a very superficial one, and when an effusion of blood has taken place this fact is at once apparent. It is not at all an unusual occurrence for the blood effused to be very considerable in amount, even so great as to cause the patella to be pushed up away from its normal position. It has been noted in quite a considerable number of these cases that the effusion, instead of disappearing, becomes chronic, the hemorrhagic effusion being replaced gradually by a serous one, and the joint then presenting the characteristic features of chronic synovitis. It is very unusual for suppuration to occur after injuries of this kind. The joint is much more apt to remain chronically inflamed without presenting at any time evidences of an acute inflammation.

A diagnosis is readily made from the history of the case and from the symptoms enumerated above.

Complications.—In addition to the chronic inflammatory condition mentioned above, one may sometimes find that the semilunar cartilages have become displaced because of the trauma. Should the injury have been sufficiently severe to cause rupture of any of the ligaments, permanent damage may ensue, because the knee-joint depends entirely upon its ligaments for strength. "No real concavities or convexities of the bones exist. The crucial ligaments (Figs. 305 and 306) are adjusted to limit extension, to control the movements of the femur

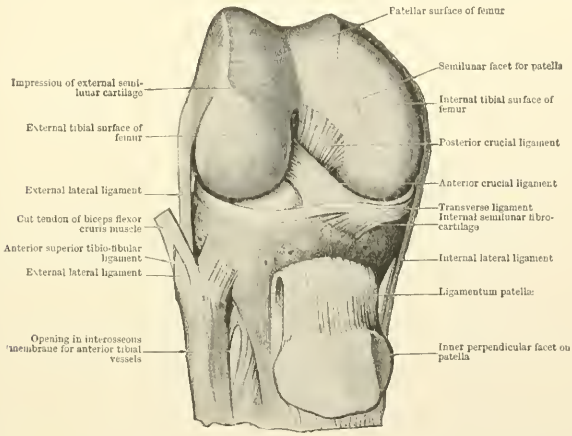

Fig. 305.—Dissection of the Knee Joint from the Front; Patella thrown Down. (From Cunningham's "Textbook of Anatomy.")

and tibia in the antero-posterior plane, to carry some of the weight when the leg is swinging clear of the ground, and possibly to assist in producing close contact of the joint surfaces in internal rotation. The semilunar fibro-cartilages (Fig. 307) may be considered as the semicircular remains of complete interarticular fibro-cartilage discs with the centres worn through, leaving sharp free edges directed toward the tibial spines and a thick periphery still attached to the inside of the capsule. The fully extended knee does not admit of lateral motion or rotation. These movements are present to some degree with slight flexion, and increase up to right-angled flexion, after which they again diminish. Extension is limited by the crucial and lateral ligaments. After rupture or section of the posterior crucial ligament, extension is still further increased by rupture or section of the anterior crucial, and, later, after rupture of the internal and external lateral

ligament. The oblique or posterior ligament of Winslow resists this motion but little, if at all. Flexion is limited by the contact of the soft parts. External rotation (supination) is limited by the two lateral ligaments, and becomes more extensive after a section or rupture of either. Internal rotation (pronation) is limited by the internal lateral and anterior crucial in combination, and becomes more extensive after section or rupture of either. A slight forward slipping of the tibia on the femur is possible in external rotation, but is stopped first by the anterior crucial and later by the two lateral ligaments. A slight backward slip-

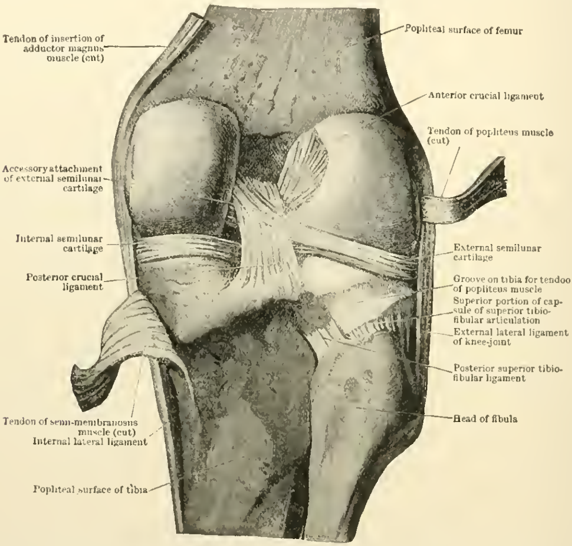

Fig. 306.—The Knee Joint Opened from Behind by the Removal of the Posterior Ligament. (From Cunningham's "Textbook of Anatomy.")

ping of the tibia on the femur is also possible in external rotation, but is limited first by the posterior crucial and later by the two lateral ligaments.

"Adduction and abduction are also possible in external rotation to a degree which can be felt with the hand on the joint. Adduction is limited first by the external lateral ligament, and later by the posterior crucial. It is also increased on the cadaver after removal of the internal semilunar. Abduction is limited first by the internal lateral, and later by the posterior crucial ligament. On the cadaver, abduction is greater after removal of the external semilunar." (Benjamin Tenny, M.D.: *Annals of Surgery*, Vol. XL.)

Penetrating Wounds of the Knee Joint.

Every penetrating wound of the knee joint is serious and demands the most careful attention. These injuries were very serious in the pre-antiseptic days, but the prognosis is very much better with present methods of treatment. Small wounds often close spontaneously or by primary union, with the retention of perfect movement of the joint.

Symptomatology and Course.—The clinical course depends upon whether the interior of the joint becomes infected or not. In the absence of infection the wound closes readily with no untoward local or constitutional symptoms.

In an infected knee there are the ordinary symptoms of acute inflammation with fever, often preceded by a chill. The pain is usually severe and the swelling marked.

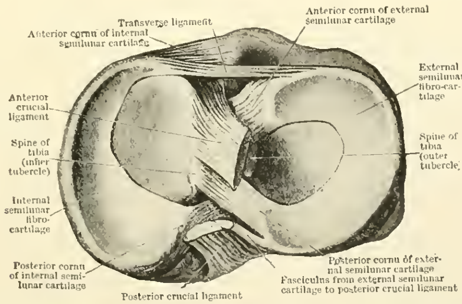

Fig. 307.—Upper End of Tibia, with Semilunar Cartilages and Attached Portions of Crucial Ligaments. (From Cunningham's "Textbook of Anatomy.")

The constitutional symptoms are, as a rule, severe and threatening. Severe pain accompanies every attempt at movement, and all manipulation of the joint produces marked pain; even the weight of the bedclothes being frequently intolerable. The joint is often as exquisitely tender as when it is the seat of an acute articular rheumatism.

Septic poisoning of a very severe type sometimes supervenes, and the patient may succumb to pyæmia or septicæmia.

Diagnosis.—The diagnosis is usually easy, but it is sometimes difficult because of the small dimensions of the wound in the skin. The use of an aseptic probe in aseptic hands, after the skin has been thoroughly sterilized, is permissible when other means of diagnosis are not sufficient to establish the fact of penetration; but the greatest care must be taken to avoid carrying infection into the depths of the wound.

Complications.—Tetanus may supervene here as elsewhere, especially in small punctured wounds.

Hemorrhage into the joint cavity is by no means unusual. The hemorrhagic effusion forms a good nidus for the spread of infection.

Extensive splintering of the bones in the vicinity of the joint is often a marked feature in gunshot wounds. This statement is particularly true of the old, heavy bullets possessed of but low velocity. The modern bullet does not

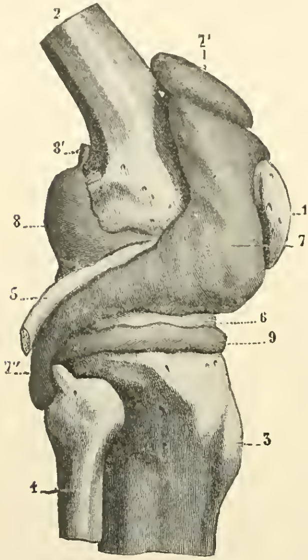

FIG. 308.—Synovial Pouch of the Knee Joint Seen from the Outer Side of the Limb. (After Poirier.) 1, Patella; 2, femur; 3, anterior tuberosity of the tibia; 4, fibula; 5, tendon of the popliteus muscle; 6, interarticular cartilaginous disc; 7, anterior and superior portion of the synovial pouch; 7′, upper cul-de-sac, sometimes separated from 7 by a membranous partition; 7″, popliteal prolongation of the pouch, 8, posterior or condyloid portion of the pouch; 8′, an extension or process of the pouch which is rarely absent and which is the starting-point of popliteal cysts; 9, lower portion of the synovial pouch, lying between the semilunar fibro-cartilages and the tibia.

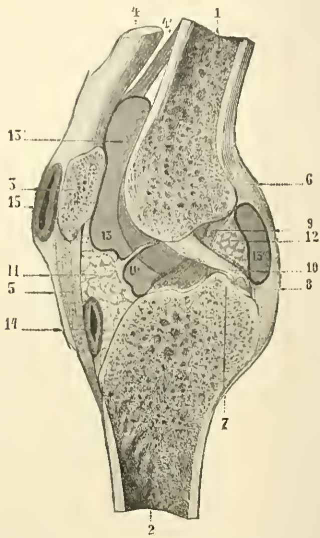

FIG. 309.—Antero-posterior Vertical Section of the Knee Joint. (After Testut.) 1, Femur; 2, tibia; 3, patella; 4, triceps muscle; 4′, muscular fibres which serve to render the synovial pouch tense; 5, ligamentum patellæ; 6, posterior ligament of the knee joint; 7, spine of the tibia; 8, posterior tubercle of this spine; 9, anterior crucial ligament; 10, posterior crucial ligament; 11, anterior cushion of fat and connective tissue; 11′, ligamentum adiposum; 12, posterior or intercondyloid cushion of fat and connective tissue; 13, synovial pouch of the knee joint, 13′, upper cul-de-sac of this pouch; 13″, posterior portion of the pouch; 14, serous bursa lying behind the ligamentum patellæ, 15, serous bursa lying in front of the patella.

inflict nearly so much injury upon the osseous structures. (This subject is fully considered in Volume II.)

Treatment.—In absolutely fresh incised or punctured wounds every effort should be made to prevent infection. Apply an aseptic dressing after the sur-

rounding area has been thoroughly sterilized. Immobilize the joint. In the absence of pain, fever, or other indication of infection, permit the primary dressing to remain *in situ* unless it should become soiled. Staining of the bandage calls for an immediate change of dressings. The majority of non-infected wounds will heal under the primary dressing; hence it should remain undisturbed unless there is a positive indication for changing it.

If fever appears or severe pain supervenes the dressings should be removed and the region examined carefully. These symptoms render an investigation of the interior of the joint necessary. An aspiration of the cavity will determine the character of the fluid. Cultures made from the fluid removed by aspiration will reveal the nature of the infecting organism. Should a purulent fluid be withdrawn an immediate, thorough evacuation and washing out of the interior of the joint, with subsequent drainage, are urgently indicated. Early evacuation of the pus combined with free drainage will do much to limit the spread of the inflammatory process and at the same time materially reduce the severity of the systemic infection. Such procedures are both limb- and life-saving measures.

In many of the milder cases extensive opening of the joint is not necessary, but the incisions should be so placed as to insure the most thorough and complete drainage of the articular space. Hueter has recommended incisions at the outer side, beneath the patella; on the inner side; and at the upper margin of the synovial pouch. Incisions upon either side of the quadriceps tendon, an inch in length, and two below the patella in front of the lateral ligaments, give free entrance to the joint and permit good irrigation of the synovial sac. Ollier makes two lateral incisions behind the condyles, the outer at the anterior border of the biceps tendon and the inner between the semitendinosus and the semimembranosus.

None but bland, non-irritating fluids like normal salt solution, two- or three-per-cent solutions of boric acid, or very weak formalin mixtures are permissible for the purpose of irrigation. Some surgeons prefer to omit all irrigation of these inflamed joints, believing that the introduction of fluids, no matter how bland, adds to, rather than diminishes, the inflammatory process. Irrigation may be dispensed with if free outlets for the pus are provided.

Drainage tubes and gauze should be inserted into the joint through the openings described above. As drainage is more free when the knee is flexed, it may be advisable to secure the limb in this position, at least until the danger of ankylosis be impending; then it should be kept straight for apparent reasons. Hot, moist dressings are to be preferred to dry ones.

The treatment outlined above will frequently cause the inflammatory process to become limited to the anterior, more accessible portion of the joint; in fact, this plan of treatment will, in a large proportion of the cases, bring about quick amelioration and rapid subsidence of the disease. But, if the

above plan of treatment proves ineffectual in combating the inflammatory process, one should open the joint by means of an incision similar to that employed in making an excision. W. J. Mayo advises sawing through the patella in order to gain free access to the cavity. Other surgeons have advised the complete removal of the patella under similar circumstances. There can be no question as to the absolute necessity of obtaining the freest possible access to the joint and of providing for complete drainage from every part of the cavity. After the joint has been thus freely opened one will often find such extensive involvement of the synovial membrane as to require its complete removal. Every part of this membrane, together with a liberal amount of adjacent structures, may be removed with benefit to the patient; the semilunar cartilages and crucial ligaments may also be sacrificed.

Posterior incisions, *i.e.*, through the popliteal space, would seem, at first blush, to be valuable adjuncts to the anterior and lateral ones, because such incisions would be ideal ones through which to drain the more inaccessible posterior portion of the joint, especially when, as is always the case, the patient must assume the recumbent position during the period in which drainage is employed; but the distance of the articular cavity from the surface of the skin, the importance of the structures located in this region, and the very great danger of causing an extension of the trouble by infection of the cellular and fatty structures which are found here, interdict the employment of drainage of the knee through the popliteal space. When the posterior portion is involved, drainage is much facilitated by complete flexion of the joint, this manœuvre tending to throw the head of the tibia forward and thus permit of a much more complete evacuation of the fluids. It is sometimes advisable to fix the limb in complete flexion and treat the open cavity by wet dressings during the active period of the inflammation. Such a procedure, however, is advisable only in those very severe cases in which an ankylosed joint is an inevitable sequel, because the maintenance of this position for any length of time will necessitate an excision of the bony portions of the joint when attempts are made to restore the parts to their normal relations.

The surgeon is often called upon to treat this class of cases after the pus has forced its way through the enveloping membranes of the joint and has invaded the surrounding tissues. Many of these cases are not recognized as being due to a septic arthritis and are treated for rheumatism, their true nature not being suspected until fluctuation is discovered in the surrounding parts. It is by no means unusual to find large collections of pus in the thigh and sometimes in the leg when the patients have been subjected to "expectant" treatment. This complication is deplorable because it adds materially to the severity of the septic complications and also because it renders amputation a much less satisfactory procedure, owing to the fact that the section must, of necessity, be done through tissues already infected. This complication is espe-

cially apt to happen when pus accumulates in the upper synovial pouch because of the flexed position of the thigh. Therefore the early closure of this pouch by means of direct pressure will delay and may obviate the complication.

A spreading cellulitis of the thigh is sometimes mistaken for erysipelas because of the advancing redness of the skin. Such a mistaken interpretation of the symptoms gives the pus added opportunities for burrowing among the tissues and materially increases the probability of an unfortunate termination. Purulent collections in the tissues outside of the joint call for early, free incisions and adequate provision for drainage.

Medical treatment is of avail in these cases only when used in conjunction with active surgical measures. Strychnia, whiskey, or other stimulants may prove of value in assisting the patient during the period of septic intoxication. Concentrated foods are essential in maintaining the strength of the patient.

The antistreptococcus serum, administered in association with incision and drainage, often seems to prove of signal value in combating the general septic condition and it should be employed. The serum comes in packages, so prepared as to be ready for hypodermatic use. The usual dose is 10 c.c. It may be repeated in four hours, should no improvement in the general symptoms be observed within that period of time. The author has never noted any bad results from the use of the serum, but has, on the other hand, seen remarkable and permanent improvement follow its administration. Its value is beyond doubt in those cases in which streptococci are responsible for the joint infection.

The question as to how long one is justified in persisting in the treatment of the joint before resorting to amputation is one which calls for much good judgment on the part of the surgeon. No one would think for a moment of amputating the limb so long as there is a chance of saving both life and limb; neither should one hesitate to resort to the removal of the limb when, in his judgment, the life of the patient is seriously threatened. True conservatism may be shown by a resort to amputation before the patient is utterly exhausted by sepsis. If early incision, with plenty of provision for drainage, does not control the situation, amputation is imperatively demanded.

A joint which has been the seat of a septic arthritis will, almost without exception, be more or less ankylosed after the active process has subsided; and it not infrequently happens that because of the greater ease obtained by the patient when the inflamed knee is bent, a greater or less degree of flexion will be combined with fixation. The employment, however, of **traction** applied to the leg, or the application of Sayre's knee-joint extension splint, will, in our experience, afford comfort and proper extension at the same time.

Treatment designed to overcome the resultant stiffness of the joint must be undertaken cautiously. Too early manipulation may lead to a recrudescence of the active inflammation. Hot applications followed by light massage of the structures above and below the joint should be the initial steps. Mas-

sage over the region of the joint should be associated with the former measures at a later date. Passive and active movements may then be undertaken, but they should be very gentle until tolerance is established. If these measures cause pain and effusion they should be omitted for two days, the joint in the mean time being snugly bandaged and surrounded with hot-water bottles. It should be an invariable rule to abstain from subjecting the joint to movements during the persistence of any symptoms of acute inflammatory reaction, because, unless this precaution is taken, the entire joint may again become the seat of active inflammation. Should the parts prove tolerant of movements, their range may be increased gradually until the limit is reached.

Hard-and-fast ankylosis with a good position of the limb may be regarded as a favorable result in the more severe cases. These patients seldom suffer with pain in the region of the articulation, but patients with a limited range of movements frequently complain of severe, intractable pain.

Fixation of the patella sometimes results from an acutely inflamed joint. Attempts to remedy this condition by chiselling the patella away from the structures to which it is adherent have not been followed by very satisfactory results. Removal of this bone, while more radical, is more efficient.

Breaking of the adhesions, with the patient fully anæsthetized, may result in benefit provided the individual will bear the pain inflicted by subsequent movements of the joint. Children will not often coöperate with the physician; hence they may require an anæsthetic on several occasions. The ultimate outcome will depend largely upon the persistency with which the patient follows out the treatment. Many of these joints ultimately become fixed and incapable of any movement—this, too, in spite of reasonably faithful attempts to follow out the suggestions of the surgeons.

Resection will be necessary when the joint becomes ankylosed in a position which does not permit the patient to use it for locomotion. If resection is impossible, or should it prove unsatisfactory, the limb may be amputated.

Helferich, Cramer, Chlumsky, Mikulicz, Murphy, and others have been gradually perfecting a method by means of which movable joints may be secured by interposing substances between the joint surfaces in order to prevent readhesion of these structures. Helferich, in 1899, suggested the possibility of using the vastus internus for this purpose. Various substances, such as plates of silver, celluloid, zinc, rubber, decalcified bone, ivory, and magnesium, have been interposed to prevent new adhesions from forming, but the results have been disappointing. The researches of J. B. Murphy (*Journal of the American Medical Association*, May 20th, 27th, June 3d, 1905) as to the value of interposing layers of fascia, adipose tissue, or muscle, seem to indicate the positive value of this method, but more work and later reports are essential before one can say that the problem has been solved.

The Ankle.

Sprains of the Ankle.

Sprains occur at this joint more frequently than at any other articulation. The weight of the body acting in an abnormal direction is the power which is usually responsible for the forcible movements in which the normal range is exceeded.

The most common cause is that of forced inversion of the foot. This accident often occurs while a person is walking; a misstep or an unevenness of the surface may result in the foot being turned inward, and the weight of the body coming upon a foot in this position serves to cause further inversion.

Hypereversion is a less frequent cause of a sprain of the ankle, because of the great strength of the ligaments on the inner side of the joint. Injuries of this sort not infrequently result in a fracture of the lower end of the fibula with or without a tearing off of part of the internal malleolus.

Sprains from inversion are sometimes produced by a person jumping and alighting upon a stone or inequality of the surface.

The same injury often happens in the act of skating. Under these circumstances the sprain is apt to be a severe one, because the sharp runner of the skate fixes the foot so that it cannot yield to the pressure of the weight of the body.

In some cases the injury is caused by the foot becoming caught in an excavation or groove, and the body falling violently to one or the other side. The mechanism of the injury is very simple: instead of the weight of the body being projected along normal lines it is applied while the foot is in an unusual position; hence the strain is exerted upon structures not usually called upon to sustain the weight of the body. The unexpected strain finds the tissues unprepared for the task, and they yield under the unlooked-for call to action. The ligaments and tendons, being inelastic structures, are forcibly stretched or ruptured, and the normal function of the joint is impaired in proportion to the extent of damage done these structures. A fracture is sometimes the result of similar violence.

Symptoms.—The first symptom is pain produced by the sudden application of the force to the unprepared tissues of the ankle. The patient may fall from the giving way of the joint, but ordinarily he will quickly shift his weight to the sound leg and raise the injured one from off the ground. So soon as the weight is removed the severe pain disappears in part, but the application of the foot to the ground causes its prompt recurrence. The patient, by reason of the pain produced by placing any weight upon the injured ankle, will hop to an object of support. Within a comparatively short time, swelling in the region of the joint will appear, and associated with this there will be a general stiffen-

ing of the parts. Active as well as passive movements will induce pain, and the muscles which fix the joint will remain in a state of tonic contraction. Ecchymoses may appear in the skin within a few minutes, but ordinarily several hours will elapse before signs of extravasation become evident. An abnormal range of motion will be present if extensive laceration of the ligaments has taken place; lateral motion may be detected, but as a rule this is prevented by the osseous elements of the joint.

Diagnosis.—The history of the case, combined with a negative radiogram, will enable the surgeon to make a correct diagnosis. Unfortunately the radio-

Fig. 310.—Gibney's Method of Applying Adhesive Plaster in Cases of Sprain of the Ankle. *a* shows the manner of applying the first strip; in *b*, three additional strips are shown in position; in *c*, the final position of all six strips is shown. (Some surgeons prefer to use a larger number of strips.) The small numbers in the diagrams indicate the order in which the different strips should be applied.

gram cannot give one any idea of the actual condition present, but it is of great value in ruling out the possible existence of a fracture.

Complications.—These are fortunately unusual. The author has seen one case in which a rupture of the tendo Achillis took place in connection with a severe sprain of the ankle. The tendon ruptured about one inch above its point of insertion into the os calcis. Pott's fracture sometimes occurs.

Treatment.—The best and quickest results will be obtained by the immediate use of heat or cold as described above, followed first by gentle massage and afterward by firm bandaging of the foot and lower part of the leg. At the end of twenty-four hours adhesive plaster should be applied in the manner recommended by Gibney. (Figs. 310 and 311.) After it has been applied the patient should be encouraged to use the joint to a reasonable extent, unless there is indubitable evidence of extensive laceration of the ligaments or tendons. Early use of the joint brings better results than does enforced, prolonged rest.

It is advisable to dispense with all fixation apparatus at the earliest possible moment, lest permanent disability follow in the wake of an over-zealous application of immobilizing dressings.

Many of these cases do very well when the joint is immediately and continuously used. The author recalls a personal experience bearing upon this point. While engaged in fishing he "turned his ankle" upon a rock in the bed of the stream. The pain was intense and he was compelled to hop to the bank in order to sit down and examine the limb. Finding that no bones were broken, and being compelled to travel, entirely alone, a couple of miles to

Fig. 311.—Photograph Showing Side View of an Ankle to which Strips of Adhesive Plaster Have Been Applied in the Manner Recommended by Dr. V. P. Gibney. (Dr. George D. Stewart, in the "Reference Handbook of the Medical Sciences," second edition.)

reach civilization, he had no alternative save to walk that distance. The cold water of the mountain stream immediately suggested a ready means of applying cold. A cautious walk of a couple of miles in the cold water of the brook resulted in great amelioration of the pain and in a limited appearance of the swelling. A repetition of the treatment the next day led to a complete cure.

When the pain, swelling, and abnormal mobility persist after the lapse of three or four days, fixation of the joint by means of a plaster cast is indicated, but the patient should be urged to walk about with the cast in position.

The plaster cast should be used only when no other method of treatment proves of value, and it should not be permitted to remain for more than a week. When plaster of Paris is used it is much better to apply lateral strips in such a manner as not to interfere with the normal flexion and extension of the joint.

Sequelæ.—An ankle which has once been the seat of a sprain seems, in

some individuals, to remain weakened, and this weakness predisposes to future troubles of the same nature.

Stiffness, more or less permanent, may supervene upon a sprain. This condition is most frequently found in cases which have been treated by prolonged immobilization.

Laceration of ligaments in the ankle occurs without coincident fracture, and also in cases in which there is a break in the bone or bones in the immediate vicinity of the joint. In the former event (primary lacerations) effusion of blood and the presence of unnatural movements of the joint furnish sufficient evidence upon which to base the diagnosis.

It has been well said that the worst feature of a fracture near a joint is the damage done the joint. When we consider the fact that fractures at a distance from a joint usually unite without much impairment of function, one is very near the truth when he ascribes the ill effects of fractures near a joint to the involvement of the articulation and to the prolonged immobilization ordinarily employed in the treatment of the fracture. Close observation will convince one that surgeons frequently make the mistake of fixing the joint for too long a time and thereby interfere with the return of its function. Passive movements ought therefore to be begun early in all cases in which a joint is involved in a fracture.

Contusions of the Ankle.

Contusions differ from sprains only in one respect, viz., that they are the result of direct violence, whereas in sprains the force is applied indirectly. The symptoms are quite similar except for the fact that in contusions there is likely to be bruising of the skin to a greater or less degree. The diagnosis is easily made from the history of the case, the pain, the tenderness, and the impaired movement.

The treatment is very similar to that employed in sprains. When there is laceration of the skin, thorough cleansing, with careful aseptic treatment, is necessary. The prognosis depends upon the extent of the damage done the soft parts, it being understood that the case should not be classed as a contusion when the bones are broken. A contusion of the bony parts of the articulation sometimes occurs, but a consideration of this condition will be taken up elsewhere.

Crushes of the Ankle.

Crushes of the ankle joint frequently occur in railway injuries and in injuries caused by the falling of heavy weights. Heavy vehicles may, being drawn over the leg, cause extensive or clearly limited crushes involving the ankle joint. The amount of crushing may be so great as to reduce the limb to a pulp, or it may inflict a slight, moderate, or very severe injury upon the joint and the contiguous parts.

In view of the fact that injuries of this sort involve much more tissue than that of the joint, and because the joint injury is of secondary importance, the question of treatment will not be gone into very extensively here. It is sufficient to say that if the injury is not severe enough to require amputation, great care should be taken to place the parts in the best position for future usefulness, because permanent ankylosis at the ankle is likely to occur. The foot should be placed at right angles to the leg and fixed in that position. The dressings should be so arranged as to prevent the toes from falling forward. This tendency can be overcome by carrying the fixation dressing beyond the ends of the toes, or the toes may be held up by "guy ropes" of bandage applied around the toes and attached to fixed points above. A modification of Gower's splint meets the indications very fully.

Incised Wounds of the Ankle Joint.

Incised wounds of the ankle joint are uncommon because of good lateral protection, but occasionally one is called upon to treat an incised or punctured wound of this joint. The ankle joint has been opened by wounds inflicted by a scythe or a sickle. Incised wounds of this joint may be acaccompanied by injury to the tendons.

Symptoms.—The characteristic symptom of penetration of the joint is escape of synovial fluid. In the absence of this symptom the diagnosis will have to be made by introducing a sterile finger or probe into the cavity. The wound should not be explored until the parts can be rendered aseptic.

Complications.—Division of tendons may be part of the picture of the case. Infection of the joint with pathogenic bacteria may occur and will of course add greatly to the seriousness of the situation. Hemorrhage is not likely to be severe, but when the dorsalis pedis artery is divided the bleeding may be quite free.

Treatment.—The best treatment is that which gives the least opportunity for the entrance of infecting organisms. The laity has become intelligent regarding the seriousness of wounds of this nature, and proper protection is given the wound between the time of its infliction and the advent of the surgeon. It is very unusual at the present time to find these wounds smeared with shoemaker's wax or spider webs, etc.; hence the likelihood of infection is reduced.

When first seen, wounds of this character should be very carefully disinfected in the usual manner adopted for the preparation of the skin for surgical operations. The use of strong antiseptics in the interior of the wound is not advisable, because of the added irritation thereby induced. If there is a possibility of tendons having been divided, the wound should be enlarged and the ends of the divided tendons approximated.

As a rule, the wound should not be sutured tightly throughout, because this

interferes with drainage. A wisp of gauze or silkworm gut may, if needful, be introduced into the depths of the wound for drainage. A bulky dressing of aseptic or antiseptic gauze covered with absorbent cotton should be held in position over the wound by a snug bandage.

If there is no rise of body temperature or other indication of infection at the end of forty-eight hours, the gauze drain should be removed and the dressings reapplied. The dressings should now be left *in situ* unless some indication (fever, pain, or redness) for their removal occurs. The fewer changes of dressings the less likelihood of infection.

Movements should be begun when the interior of the joint has been shut off by granulations, because prolonged fixation may result in permanent impairment of the joint.

If, on the other hand, symptoms of infection of the joint supervene, free incision and drainage should be employed. The original incision may be enlarged or new incisions may be made. The rule is that sufficiently free incisions are not made and much damage results from their absence. Irrigation of the joint is not necessary if sufficiently free drainage is provided. When irrigation is employed, only the mildest fluids should be used.

Should incisions and drainage fail to control the process, amputation or excision may become imperative. An amputation usually means that sufficiently free drainage had not been provided. Excision of the joint is but seldom indicated.

The Feet.

Sprains and contusions of the feet are not uncommon. Care must be taken not to confuse these injuries with fractures of the tarsal or metatarsal bones, it being easily possible to avoid this error by means of skiagrams.

The treatment is similar to that laid down above for the treatment of sprains and contusions elsewhere.

The most frequent open wounds found in the foot are those produced by bullets, but punctured and incised wounds sometimes occur. Any wound that opens one of the joints of the foot must be looked upon as one which may cause very serious, even fatal, trouble unless treated early with a view to the prevention of infection. Whenever the tissues of the sole of the foot become involved in a suppurative process one is apt to have a very formidable condition to combat. Free incisions with ample drainage may, and often will, save the foot, but in some cases amputation alone will save the life of the patient. The use of a continuous bath of a hot bichloride-of-mercury solution (1 : 10,000) often proves of signal service in arresting a threatening infection. Moist applications, as a rule, prove more grateful to the patient than dry dressings, and they often seem to exert a more beneficial influence upon the course of the disease.

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